FIREPROOF CONSTRUCTION.

EXPANDED STEEL

IN

ARMOURED CONCRETE

AND

PLASTER CONSTRUCTION.

E. A. Cooke, Representative,
183, Gt. Brunswick St.,
Dublin.

EXPANDED STEEL IN ARMOURED CONCRETE: Catalogue of the New Expanded Metal Co. of Westminster, illustrated with photographs of work in progress on various projects, and views of buildings made of reinforced concrete. Oblong 4to, pp.112, orig.boards. ca.1903.

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EXPANDED STEEL
IN
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AND
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FOR

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WAREHOUSES, FACTORIES, POWER HOUSES,
SHEDS, SILOS,
DWELLINGS, VAULTS, STORAGE BINS, DRY KILNS,
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PIERS, DRY DOCKS, TUNNELS, CANALS, FORTIFICATIONS,
RETAINING WALLS, SEPTIC TANKS,
EXHIBITION BUILDINGS,
ETC., ETC.

PUBLISHED BY
THE NEW EXPANDED METAL COMPANY, Ltd.,
YORK MANSION, YORK STREET, WESTMINSTER,
LONDON, S.W.

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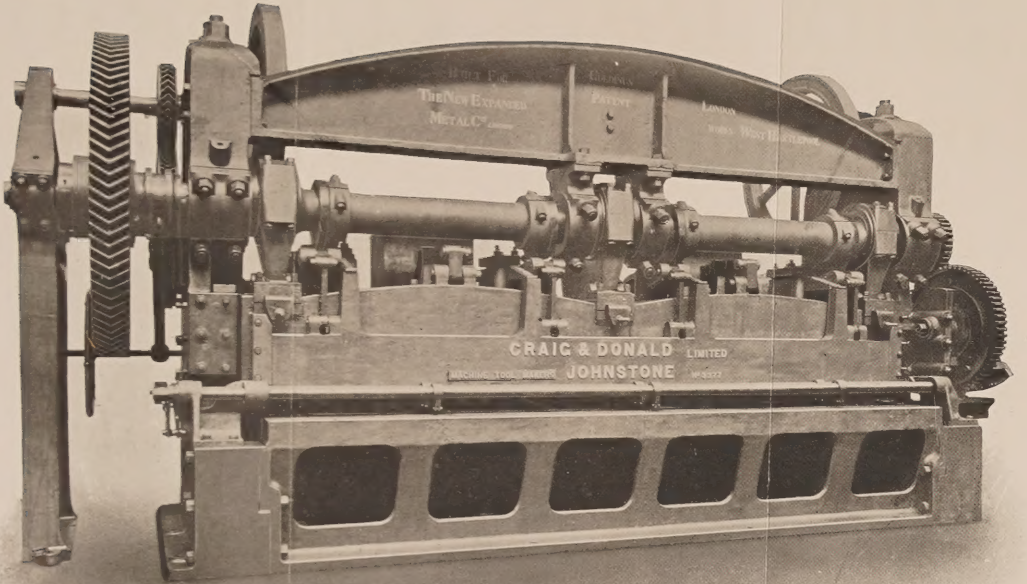

MACHINE FOR PRODUCING EXPANDED METAL UP TO 16 FEET LONG WAY OF MESH.

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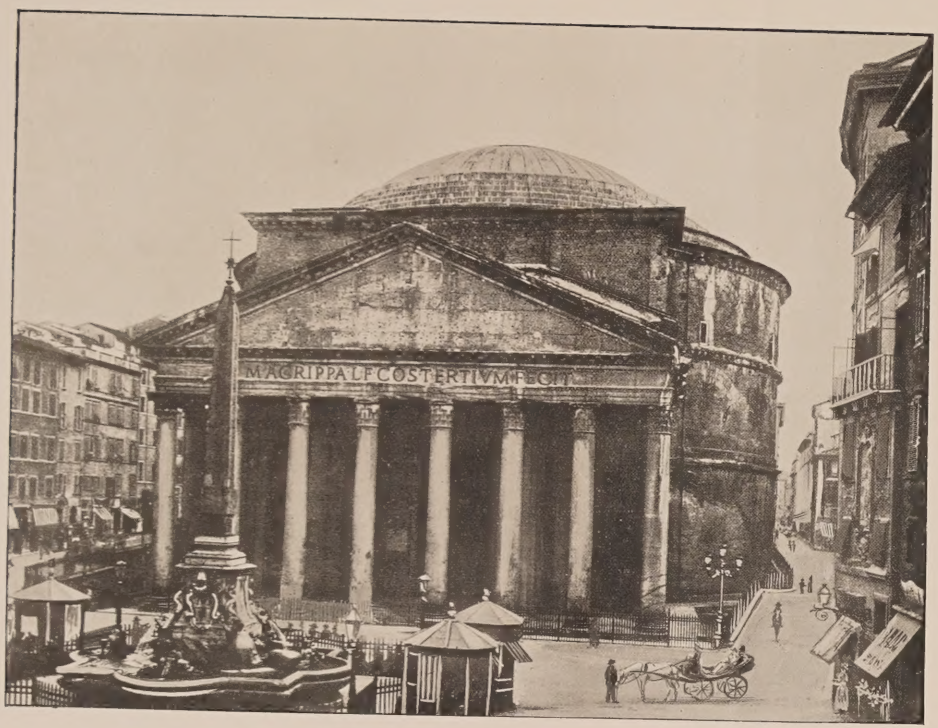
Note.

THIS Work must not be taken as exhaustive of the uses to which Expanded Metal is adapted, as the material is constantly being put to some new use. Moreover, no attempt has been made to shew a complete collection of the buildings, and other works, into which it has been introduced, the compilers considering it sufficient for the purpose in view to illustrate and describe a number of works on various systems of construction.

It is hoped that this book may be kept for purposes of reference, and any information on the uses of Expanded Metal not contained in it will be supplied upon application to:—

The New Expanded Metal Company, Limited,
York Mansion, York Street,
Westminster, S.W.

E. A. Cooke, *Representative,*
183, Gt. Brunswick St.,
Dublin.



THE PANTHEON OF AGRIPPA AT ROME.

Concrete Construction over Nineteen Centuries old, and in service to-day.

Concrete Construction

(Historical)

CONCRETE Construction is no new thing to the world, although for a time it seems to have lapsed to a place among the "lost arts" of civilization.

The Romans were the first, so far as is known, to use concrete to any considerable extent, and a number of their works are standing at the present day, although they were built with "Pozzuolana," which was greatly inferior to modern Portland Cement. The Pantheon, which is the most perfect existing classical building in Rome, was built by Agrippa in 27 B.C. The walls of the circular part are nearly 20 feet in thickness, while the roof is a hemispherical concrete dome of 142 feet 6 inches span, with a circular opening in the centre about 30 feet in diameter. It does not show a single crack to-day, and one cannot doubt, as he views this magnificent structure, that the successes of the early Roman builder in applying cement concrete in important engineering and architectural operations will be surpassed in the present generation. The works of the early Roman architects and builders in cement concrete, that have endured the ravages of time and still exist side by side with natural stone, are sufficient evidence of the fact of the durability of concrete in building construction. The production of a cement suitable for this class of construction was discontinued, and remained for ages among the lost arts until 1824, when the discovery of a process for treating limestone gave the world Portland cement. Since the date of its first manufacture a continual improvement has been made in its quality, until to-day cement of superior quality is being manufactured in every part of the world. The modern builder has familiarized himself with its advantages and studied its nature. The manufacture of cement has become a science and its application is studied by all the most progressive engineers of the world, and the specialist in concrete construction was the natural outcome of the rapid progress made in adapting cement to many and varied uses and conditions. Judging from the record of the past few years of the wonderful progress made in Europe and America in developing a true understanding concerning cement and its uses, it is safe to prophesy that the engineer and the architect of the present day will give to posterity examples of their best creations, built of steel-armoured cement concrete.

Sufficient has already been done to demonstrate beyond a shadow of a doubt, the reliability of this material to withstand all climatic changes. Not only will the plain, massive work withstand the wear and tear of extremes of temperature, but the most elaborate of cornices and the finest of mouldings and enrichments may be used with no fear of deterioration or of disintegration.

During the many centuries intervening between the practices of the ancients (as described by Vitruvius), down to almost our own time, the manufacture of cement and uses of concrete underwent but little change. According to him, the Roman mortar was made with lime simply fused and slaked and obtained by burning sometimes limestone, and sometimes merely shells, there being but little difference between the mortar used in plastering operations and that employed for bonding together masses of sand and pebbles into what most nearly approached to our modern concrete. The excellence of the Roman concrete owed its qualities far more to the employment of the volcanic "Pozzuolana" which possessed qualities of its own, not depending altogether upon the lime with which it was mixed.

The real impetus to the extensive use of cement in modern times was given by the experience of John Smeaton, who in 1756 discovered the hydraulic principle of cement in the course of his experiments with all the then known materials of which mortars and concretes were composed. Between 1796 and 1820 great progress was made in the manufacture of hydraulic cement by the Englishman, Parker, and the American, White, upon the lines which had been indicated by their illustrious predecessor, but it remained for Joseph Aspdin, of Leeds, to finally produce that wonderful product which he named "Portland Cement," because of its resemblance in colour to the well-known Portland stone. The invention of Aspdin, however, languished for almost 20 years, until it was taken up by the firm of J. R. White & Sons in 1845, since when the industry has grown to huge proportions in every civilised country.

"Monier" Construction.

JEAN Monier, a gardener living in the neighbourhood of Paris, is generally given credit for the invention, in 1876, of the system of construction which, for five-and-twenty years, has been called by his name, although François Coignet, of Paris, had taken out Letters Patent in 1869, on a combination of iron and concrete, and a building had been constructed by W. E. Ward, in 1875, near Port Chester, New York,* in which "not only all the external and internal walls, cornices, and towers were constructed of *beton* (concrete), but all of the beams and roofs were exclusively made of *beton*, reinforced with light iron beams and rods."

In 1876 Monier needed some large pots in which to plant orange trees, and he conceived the idea of using concrete with wire netting embedded in it to give strength. He received a diploma at the Paris Exposition of 1878, and, finding that his invention covered a much larger field than he had supposed, brought the matter to the attention of engineers and capitalists, with the result that, in a comparatively short time, many tanks, bridges, sewers, and the like were built on his system in France, Germany, and Austria. It was only a step from this to the construction of fire-proof floors, large numbers of which have since been built in Europe.

The modern theory of beams assumes that, when a beam or plate is supported at the ends and loaded at one or more intermediate points, there is a horizontal plane, usually near the centre, in which the particles are subject to neither compression nor tension. All particles above this "neutral plane" are in compression, and all particles below it are in tension, the intensity of the stress varying with the distance from the neutral plane.

It is well known that concrete, though an excellent material in compression, has very little strength in tension, while, on the other hand, the light steel members used in the Monier system would be of little value in compression, as they would have a tendency to buckle, but when used in tension they can be relied upon with perfect safety.

By combining the concrete in compression with the steel in tension an ideal form of construction is produced, which gives most remarkable results and is capable of wide application. It is only necessary to supply sufficient steel at all points where it is possible for the structure to come in tension. The most economical position for the steel is, of course, as near as possible to the lower surface of the concrete, where its "moment of resistance" is greatest.

The chief objection to the Monier system is that a large number of rods must be used. It is necessary to weave these rods together, or to lattice them and secure them with wire at their intersections. As these rods are usually placed but two or three inches apart, this is a tedious and expensive operation, and one which requires considerable care on the part of the mechanic, for the network of steel must be kept near the lower surface of the concrete in order that its full benefit may be available, while, at the same time, the rods must be entirely embedded in the concrete.

Expanded Metal.

SOME six or seven years ago it occurred to John F. Golding that Expanded Metal was not open to such objections, and he at once instituted a series of experiments which gave the most surprising results. By its peculiar construction a sheet of Expanded Metal lying on a flat surface touches at only one point in each mesh. When concrete is applied upon such a sheet it works around and beneath the Expanded Metal, so that the latter is entirely embedded in the concrete, but remains close to the lower surface. It is, therefore, in the position of greatest efficiency. In constructing a floor, in which many sheets of Expanded Steel are used, no elaborate means of connecting the sheets are necessary, as the form of the meshes is such that a single mesh, when embedded in concrete, is held so firmly that the steel will break before it can be pulled out of the concrete. Therefore, where sheets join, it is only necessary to allow one mesh overlap, when the concrete furnishes a perfect bond and practically unites all the sheets in one.

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* Transactions Am. Soc. M.E., Vol. iv., p. 388.

There need be no guess-work about this construction, as a given weight of Expanded Steel embedded in a concrete beam of given thickness and composition will produce certain and definite results, calculated theoretically and proved by numerous tests and experiments.

The A B C of the Subject.

THE introduction of steel as a member of a slab or beam of concrete has its warrant in the fact that the construction without a tension member can be used in only a limited number of cases, where economy in weight and cost do not enter as controlling factors. The design of slabs or beams of concrete having the same span and to carry the same applied load, one with and one without the steel member, when taken as a problem for investigation, will show not only the economy of the introduction of the metal, but the possibility of use of the reinforced as against the impossibility of use of the unreinforced slab. While there is a wide range in the results of investigations of different engineers who have made this problem a study, due to different assumptions by each as regards the action of concrete under extreme stress, there is still the conformity of results, proving that for all the usual spans ranging from 4 to 8 feet, there is a saving of from three to four hundred per cent. in thickness. This means an equal saving in weight to develop the same strength. All agree also that the actions with and without the metal differ in that the slab which is reinforced is elastic while the other is brittle. The reinforced beam bends appreciably before breaking, while the unreinforced one breaks before bending appreciably. Therefore, knowing as we do that all the steel must be broken by tension developed at the bottom chord, and knowing the strain developed here, and the tensile value of the steel inserted, we have a certain construction with the steel tension member, as against an uncertain one without. These characteristics, all other considerations being put aside, make a beam either safe or unsafe, according to whether the metal is used or not.

Hence we conclude that the three prevailing factors in the case—viz., possibility of construction, economy of construction, and safety of construction—all demand that we reinforce our concrete beam with its tension member of steel.

FIG. 1.

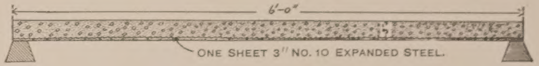
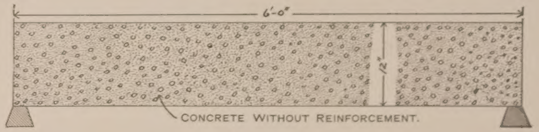


FIG. 2.



The accompanying figures 1 and 2 are designed to illustrate the consensus of opinion of engineers who have made a study of this problem. From men of unquestioned standing, who have had years of experience designing and building structures where concrete has been largely used, the value of the contentions we are making in favour of the introduction of the steel as a vital factor in the construction of various structures of concrete is conclusively shown. Steel and concrete, when used rightly together, are bound to find ready recognition in the building world. Figure 1 shows a slab 3 inches thick reinforced with a layer of 3-inch No. 10 Expanded Steel, and figure 2 a slab 12 inches thick of concrete only. Between these two thicknesses is the economic limit for the majority of cases.

One point more should be emphasized, viz., there is no form in which a given amount of steel in weight per square foot, can be better "deployed" in the slab than in Expanded Steel. Expanded Steel, notwithstanding its mesh form, is still a solid sheet, and its use gives reinforcement to every portion of the slab, and it is all in the right place.

REPORT OF TESTS

on

Expanded Steel made at the East London Technical College, on 6th June, 1899,

by Mr. D. A. LOW, Engineer.

Date of Test	5/6/99	5/6/99	6/6/99	6/6/99	6/6/99	6/6/99	6/6/99	Means.
Laboratory Mark	88A	89A	90A	91A	92A	93A	94A	...
Material	Steel	Steel	Steel	Steel	Steel	Steel	Steel	...
Area of Section: square inches ...	·029	·028	·029	·027	·03	·026	·025	...
Breaking Load: Tons	·98	·80	·82	·89	·97	·75	·80	...
Breaking Stress: Tons per square in.	33·79	28·57	28·28	32·96	32·33	28·85	32·00	30·97
Elongation in 6 inches	*	*	·063	*	*	...	...	...
Do. 8 "	...	...	...	...	...	·056	·063	...
Do. per Cent.	...	...	1·05	...	...	·70	·79	·85

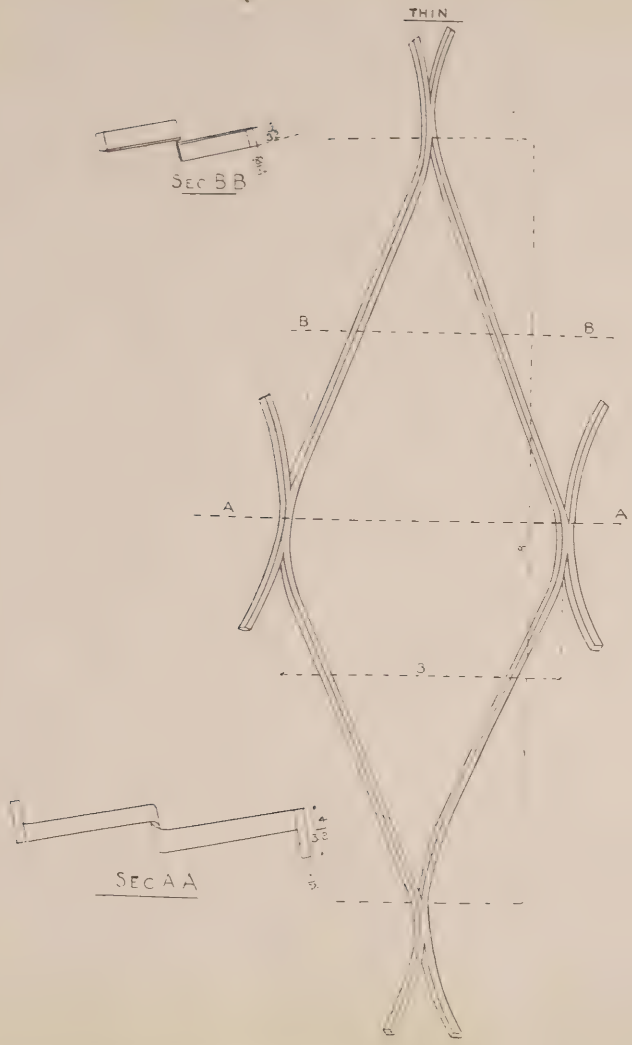
* = Fractured outside Gauge Points.

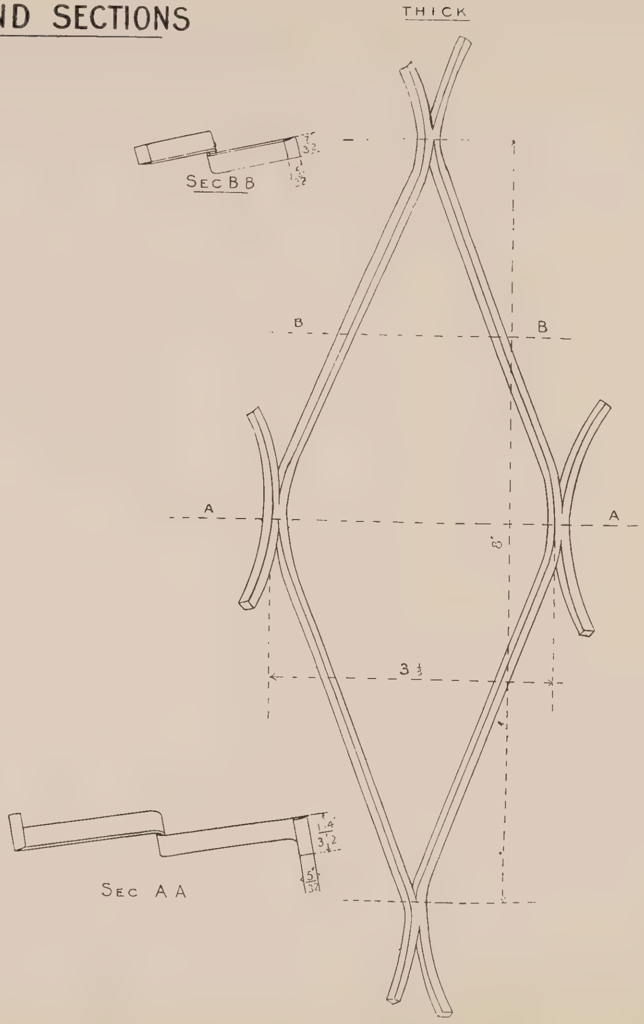
Results of Experiments to Ascertain the Tensile Strength of the following Pieces of Steel made by Messrs. David Kirkaldy & Son for the Expanded Metal Company, Limited.

Test No.	Description.	Original Ultimate Stress.				Fractured.				Stress per sq. in. of fractured area.	Extension in 2 in.		Appearance of fracture.
		Size.	Area.	Total	Per sq. in. of original areas.	Size.	Area.	Difference area per cent.			In.	Per cent.	
		Inch.	sq. in.	lbs.	lbs. tons.	inch.	sq. in.			lbs.			
II.	Pieces 1 in. wide partially sheared longitudinally												
2547	Untreated portion. Piece 1 in. by $\frac{3}{16}$in. sheared and one portion treated ...	shaped ·140 by ·202	·028	1677	59893=26·7	·090 by ·100	·009	·019	67·8	186333	0·55	27·5	Silky.
2551	Treated or stretched portion (narrower)	·139 ,, ·191	·026	1849	71115=31·8	·093 ,, ·100	·009	·017	65·3	205444	0·17	8·5	Do.
2552	Untreated...	·138 ,, ·200	·028	1771	63250=28·2	·090 ,, ·125	·011	·017	60·7	161000	0·41	20·5	Do.
	Do.												
	Treated	·137 ,, ·190	·026	1986	76384=34·1	·095 ,, ·130	·012	·014	53·8	165500	0·135	6·7	Do.
	Untreated...	·140 ,, ·187	·026	1495	57500=25·7	·095 ,, ·082	·008	·018	69·2	186875	0·58	29·0	Do
	Do.												
2548	Treated	·139 ,, ·174	·024	1656	69000=30·8	·100 ,, ·094	·009	·015	62·5	184100	0·15	7·5	Do.
2549	Mean of Untreated pieces				60214=26·9				65·9			25·7	
2550	Mean of Treated pieces	...		...	72166=32·2	...	...	...	...	60·5	...	...	7·6

DRAWING TO ACCOMPANY MESSRS FOWLER AND BAKER'S REPORT TO THE EXPANDED METAL COMPANY
DATED APRIL 29TH 1896.

EXPANDED METAL
MESHES AND SECTIONS





Report by Messrs. FOWLER & BAKER on the use of Expanded Steel in Concrete.

REPORT on Experiments made with a view to ascertain the effect of using "EXPANDED METAL" in combination with Concrete for flooring and similar purposes where strength is required.

2, Queen Square Place,
Queen Anne's Mansions,
Westminster, S.W.,
April 29th, 1896.

Messrs. The Expanded Metal Company,
H. B. Tarry, Esq.,
General Manager,
39, Upper Thames Street, E.C.

Gentlemen,

At the request of your General Manager that we should, in connection with some work we had in hand, investigate the effect of using "Expanded Metal" combined with concrete upon the strength of slabs to be used for flooring purposes, the experiments referred to in this Report were arranged and carried out by our Mr. Hurtzig.

The points to be determined were—

(1) Does the use of "Expanded Metal" in combination with concrete in the form of a flooring slab increase the carrying power of the slab, and if so, to what extent?

(2) Can a concrete slab when made without "Expanded Metal" be strengthened by the addition of more cement so as to make its carrying power equal to or greater than that of a similar slab made with "Expanded Metal?"

(3) Is a concrete slab when made with "Expanded Metal" capable of carrying as great a load as a concrete arch of the same span and same minimum thickness at the crown?

(4) What gauge of "Expanded Metal" is most suitable for use with concrete in slabs?

For the purpose of the experiments nineteen slabs and six arches were made, of the form and composition detailed in the Appendices.

The quality of the materials used was as follows:—

PORTLAND CEMENT.

Weight.—Weight of one cubic foot = 85 lbs.
Fineness.—$1\frac{3}{4}$ per cent. residue on 2,500 mesh sieve.
Strength.—560 lbs. per sq. in. neat cement after 7 days.
278 lbs. per sq. in. sand briquettes of 3 sand to 1 cement after 28 days.

SAND.

Clean Leighton Buzzard sand; weight of one cubic foot = $96\frac{1}{2}$ lbs., and of such coarseness as to be retained on a sieve of 10 meshes to the inch.

GRAVEL.

Clean Thames Ballast; weight of one cubic foot = 95 lbs.

"EXPANDED METAL."

This was of very mild steel with an ultimate resistance of 22 tons per sq. inch with 21 per cent. elongation on 8 in. Two sizes of "Expanded Metal" were used. one being 3 in. mesh with strands $\frac{7}{32}$ in. × $\frac{3}{32}$ in., the other, a stronger material, being 3 in. mesh with strands $\frac{7}{32}$ in. × $\frac{5}{32}$ in.

The concrete slabs and arches were made with the greatest care to the Specification in the Appendix. They were kept under cover and protected from frost and other severe atmospheric influences until tested, and then broken by slowly weighting them with rails, one at a time, each rail weighing about 6 cwt.

The results of these tests are tabulated in the Appendices, and the following summaries and conclusions may be drawn from them:—

(1) Strength of concrete slabs with and without "Expanded Metal":—

COMPOSITION OF THE CONCRETE.

1 of Cement, 1 of Sand, 2 of Thames Ballast, Slabs 3 in. thick.

Clear Span.			Without Expd. Metal. Breaking weight per sq. ft. uniform load. Cwts.	With Expd. Metal. Breaking weight per sq. ft. uniform load. Cwts. Expd. Metal $\frac{7}{32}$ in. by $\frac{3}{32}$ in.	With Expd. Metal. Breaking weight per sq. ft. uniform load. Cwts. Expd. Metal. $\frac{7}{32}$ in. by $\frac{5}{32}$ in.
3 ft. 6 in.	...	...	2·57	12·00	17·14
	...	...	2·57	19 73	21 43
Mean ..	...	...	2·57	15·86	19·28
6 ft. 6 in.	...	...	·46	4·61	5·08
	...	...	·46	4·61	5·07
Mean ...	...	...	·46	4·61	5·07

This summary shows that the use of Expanded Metal in the case of the 3 ft. 6 in. span increases the strength of a flat concrete slab from six to eight times the strength for carrying an uniform load that it would have if made without "Expanded Metal"; and in the case of the 6 ft. 6 in. span the strength is increased to ten and eleven times.

Experiments made by us in April, 1895, with "Expanded Metal" in combination with concrete slabs of 2 ft. 6 in. span show that with this smaller span a 3 in. mesh with $\frac{1}{8}$ in. by $\frac{3}{32}$ in. strands would give equivalent results to those obtained by the use of $\frac{7}{32}$ in. by $\frac{3}{32}$ in. metal in slabs 3 ft 6 in span.

(2) Strength of concrete slabs when made with greater proportions of cement, but without "Expanded Metal," the slabs being of the same dimensions as in other cases.

These experiments were made with a view to ascertain whether by the addition of greater quantities of cement a slab could be produced of approximately the same strength and cost as that of an ordinary three to one concrete slab made with "Expanded Metal."

It was quickly seen, as the experiments proceeded, that, so far as regards strength, the slabs made without "Expanded Metal" did not approach those made with "Expanded Metal," and that even with a neat cement slab, which would cost as much as the concrete slab with "Expanded Metal," the strength was much inferior.

The details in the Appendix of slabs nine to eleven weeks old, made without "Expanded Metal," show that although by increasing the quantity of cement the strength is proportionately increased, yet in the slab of 3 ft. 6 in. span not more than double the strength of 3 to 1 concrete is obtained, while the use of "Expanded Metal" gave eight times the strength. With the slab of 6 ft. 6 in. span the larger quantity of cement gave a strength three times that of 3 to 1 concrete, and the use of "Expanded Metal" gave eleven times.

(3) Comparative strength of concrete arches and concrete slabs with "Expanded Metal."

The mean results of the tests upon the arches of 6 ft. 6 in. span gives for the breaking load 3·72 cwts. per square foot, as against 5·07 cwts. with the flat concrete slab made with "Expanded Metal" of the thicker gauge, and 4·61 cwts. with the slab made with the thinner gauge.

The mean results of the tests upon the arches of 3 ft. 6 in. span gives 21·71 cwts. per square foot, as against 19·28 cwts. with the flat concrete slabs made with "Expanded Metal" of the thicker gauge, and 15·86 with the thinner gauge.

The quantity of concrete per square foot, and therefore the weight, in the case of the slabs is two-thirds of that in the arches of the same span and minimum thickness at the crown and with a rise of $\frac{1}{14}$th to $\frac{1}{18}$th of the span. This fact points to the utility of "Expanded Metal," in conjunction with concrete in flat slabs as a material for flooring.

The following are the mean results tabulated:—

	Relative strength under uniform load per square foot. 3ft. 6in. span. Cwts.	Relative strength under uniform load per square foot. 6ft. 6in. span. Cwts.	Relative weight pr. sq. ft. Both spans
1. Arches, 3 in thick at crown. Concrete, 1 of cement, 3 of sand and ballast ..	21·71 = 1·00	3·72 = 1·00	1·00
2. Slab with "Expanded Metal" 3 in. mesh, $\frac{7}{32}$ in. by $\frac{3}{32}$ in. strand 3 in. thick. Concrete, 1 of cement, 3 of sand and ballast	15·86 = ·73	4·61 = 1·24	·66
3. Slab with "Expanded Metal" 3 in mesh, $\frac{7}{32}$ in. by $\frac{5}{32}$ in. strand 3 in. thick. Concrete, 1 of cement, 3 of sand and ballast	19·28 = ·88	5·07 = 1·37	·66
4. Slab without "Expanded Metal." Slab 3 in. thick. Concrete, 3 of cement. 1 of sand	4·71 = ·21	1·39 = ·38	·66

In making a comparison between these results it must be borne in mind that the experimental arches were constructed with abutments of the most rigid character and their condition was somewhat more favourable than would be expected to obtain in practice, while in the case of the slabs the continuity of a floor as actually made would tend to increase the strength of the whole and a greater actual strength would be obtained than the experiments indicate.

Therefore, although the experimental arches of 3 ft. 6 in. span are slightly stronger than the corresponding slabs, in practice a floor made on either system would be of the same strength in both cases.

An actual load of 4 cwts. per square foot upon such a floor, uniformly distributed, would not exceed one-fourth of the breaking weight as shown by the experiments, and therefore would be a safe load.

(5) The most suitable gauge of metal to adopt is indicated by the experiments. The slabs made with $\frac{7}{32}$ in. by $\frac{3}{32}$ in. strand, when they failed under the load, all failed by the fracture of the metal as well as by the destruction of the concrete. Those slabs, made with metal $\frac{7}{32}$ in. by $\frac{5}{32}$ in. strand failed by the destruction of the concrete only, the metal being generally unbroken.

The conclusion is that with 3 to 1 concrete slabs 3 in. thick the metal should be slightly stronger than the lighter gauge used in these experiments, and not so strong as the heavier gauge.

A strand intermediate between the two used in the experiments or $\frac{7}{32}$ in. by $\frac{4}{32}$ in., would give the best results.

We are,
Yours faithfully,
(Signed) FOWLER & BAKER.

APPENDIX.

THE EXPANDED METAL COMPANY, LIMITED.

Particulars of Tests carried out by Messrs. FOWLER & BAKER upon Experimental Slabs for Flooring purposes, with and without the use of Expanded Metal.

Experiment No.	Number or Mark on Slab.	Date when Made.	Size of Slab.	Clear Span of Slab.	Expanded Metal.		Composition of Concrete (by volume).				Date when Broken.	Age of Slab	Total Number of Rails required to Break the Slabs.	Total Load (Uniform) to Break the Slabs.	Deflections in Centre.				Breaking Load per Square Foot.	REMARKS.
					Area and Mesh.	Strand.	Portland Cement.	Thames Ballast.	Unscreened Sand.	Water.					At $\frac{1}{4}$ Breaking Load.	At $\frac{1}{2}$ Breaking Load.	At $\frac{3}{4}$ Breaking Load.	Ultimate.		
SLABS MADE WITHOUT EXPANDED METAL.																				
			ft. ft. in.	ft. in.										Cwts.					Cwts.	
A	4	20/1/96	4 × 2 × 3	3 6	Made Expanded	without Metal	3	0	1	$1\frac{1}{8}$	23/3/96	63 days	5	30	No app	reciab	le defle	ction	4·28	Broke in centre.
B	7	20/1/96	7 × 2 × 3	6 6	do.		3	0	1	$1\frac{1}{8}$	23/3/96	63 ,,	3	18		do.			1·39	Broke in centre.
C	8	20/1/96	4 × 2 × 3	3 6	do.		3	0	1	$1\frac{1}{8}$	23/3/96	63 ,,	6	36		do.			5·14	Broke in centre.
D	9	20/1/96	7 × 2 × 3	6 6	do.		3	0	1	$1\frac{1}{8}$	23/3/96	63 ,,	3	18		do.			1·39	Broke under one timber.
E	12	20/1/96	4 × 2 × 3	3 6	do.		1	2	1	$\frac{1}{2}$	23/3/96	63 ,,	3	18		do.			2·57	Broke in centre.
F	13	20/1/96	7 × 2 × 3	6 6	do.		1	2	1	$\frac{1}{2}$	23/3/96	63 ,,	1	6		do.			0·46	Broke immediately weight was put on in centre.
G	14	20/1/96	7 × 2 × 3	6 6	do.		1	2	1	$\frac{1}{2}$	23/3/96	63 ,,	1	6		do.			0·46	Broke near centre after weight had been on for one minute.
H	15	20/1/96	4 × 2 × 3	3 6	do.		1	2	1	$\frac{1}{2}$	23/3/96	63 ,,	3	18		do.			2·57	Broke immediately in centre.
I	E	30/1/96	4 × 2 × 3	3 6	do.		3	0	0	1	17/4/96	77 ,,	3	18		do.			2·57	Carried weight of third rail one second.
J	F	30/1/96	4 × 2 × 3	3 6	do.		1	0	2	$\frac{1}{2}$	17/4/96	77 ,,	2	12		do.			1·71	Carried second rail a few seconds.
K	H	30/1/96	4 × 2 × 3	3 6	do.		1	0	1	$\frac{4}{5}$	17/4/96	77 ,,	3	18		do.			2·57	Carried third rail for one second.
SLABS MADE WITH EXPANDED METAL.																				
					ft. in. ft. in.	in. in.														
L	1	1/1/96	7 × 2 × 3	6 6	6·8 × 2 × 3 mesh	$\frac{7}{32}$ $\frac{3}{32}$	1	2	1	$\frac{1}{2}$	4/3/96	63 days	10	60	Nil.	$\frac{7}{16}$ in.	$\frac{13}{16}$ in.	$1\frac{1}{8}$ in.	4·61	Broke in the centre. The strands of metal were broken through.
M	2	1/1/96	4 × 2 × 3	3 6	4·0 × 2 × 3 mesh	$\frac{7}{32}$ $\frac{3}{32}$	1	2	1	$\frac{1}{2}$	4/3/96	63 ,,	14	84	$\frac{1}{16}$ in.	$\frac{11}{64}$,,	$\frac{1}{4}$,,	$\frac{9}{32}$,,	12·00	Broke under one timber. The strands of Expanded Metal were broken through.
N	3	17/1/96	7 × 2 × 3	6 6	6·8 × 2 × 3 mesh	$\frac{7}{32}$ $\frac{5}{32}$	1	2	1	$\frac{1}{2}$	20/3/96	63 ,,	11	66	$\frac{1}{16}$,,	$\frac{7}{16}$,,	$\frac{11}{16}$,,	$1\frac{1}{8}$,,	5·08	Broke under one timber. The strands of Expanded Metal were not broken through.
O	6	17/1/96	4 × 2 × 3	3 6	4·0 × 2 × 3 mesh	$\frac{7}{32}$ $\frac{5}{32}$	1	2	1	$\frac{1}{2}$	20/3/96	63 ,,	20	120	Nil.	$\frac{3}{32}$,,	$\frac{3}{16}$,,	$\frac{9}{32}$,,	17·14	Broke under one timber. The strands of Expanded Metal were not broken. The concrete sheared.
P	A	30/1/96	7 × 2 × 3	6 6	6·8 × 2 × 3 mesh	$\frac{7}{32}$ $\frac{3}{32}$	1	2	1	$\frac{1}{2}$	17/4/96	77 ,,	10	60	$\frac{1}{16}$ in.	$\frac{7}{16}$,,	$\frac{13}{16}$,,	$1\frac{3}{16}$,,	4·61	Just carried the weight of tenth rail one second.
Q	B	30/1/96	4 × 2 × 3	3 6	4·0 × 2 × 3 mesh	$\frac{7}{32}$ $\frac{3}{32}$	1	2	1	$\frac{1}{2}$	17/4/96	77 ,,	23	138	$\frac{3}{32}$,,	$\frac{7}{32}$,,	$\frac{3}{8}$,,	$\frac{17}{32}$,,	19·73	Carried the twenty-third rail about half minute.
R	C	30/1/96	4 × 2 × 3	3 6	4·0 × 2 × 3 mesh	$\frac{7}{32}$ $\frac{5}{32}$	1	2	1	$\frac{1}{2}$	17/4/96	77 ,,	25	150	$\frac{1}{16}$,,	$\frac{5}{32}$,,	$\frac{1}{4}$,,	$\frac{15}{32}$,,	21·43	Carried the twenty-fifth rail about half minute.
S	D	30/1/96	7 × 2 × 3	6 6	6·8 × 2 × 3 mesh	$\frac{7}{32}$ $\frac{5}{32}$	1	2	1	$\frac{1}{2}$	17/4/96	77 ,,	11	66	$\frac{1}{4}$,,	$\frac{9}{16}$,,	1 ,,	$1\frac{3}{16}$,,	5·07	Carried the eleventh rail about half minute.

Note—The average weight of rails is taken at 6 cwts. each.

APPENDIX.

THE EXPANDED METAL COMPANY, LIMITED.

Particulars of Tests carried out by Messrs. FOWLER & BAKER upon Concrete Arches, with a view to comparing with Flooring Slabs made with Concrete and Expanded Metal

ARCHES.

Experiment No.	Number or Mark on Arch.	Date when Made.	Clear Span of Arch. ft.	Clear Span of Arch. in.	Width of Arch. in. ft.		Thickness at Crown. in.	Rise of Arch. in.	Composition of Concrete. Portland Cement.	Composition of Concrete. Thames Ballast.	Composition of Concrete. Un-screened Sand.	Composition of Concrete. Water.	Date when Broken.	Age of Arch.	Total Number of Rails required to Break the Arch.	Total Load (Uniform) to Break Arch. Cwts.	Deflections in Centre. At ¼ Breaking Load.	Deflections in Centre. At ½ Breaking Load.	Deflections in Centre. At ¾ Breaking Load.	Deflections in Centre. Ultimate.	Breaking Load per Square Foot. Cwts.	REMARKS.
T	1	21/1/96	6	6	3	0	3	5	1	2	1	½	23/3/96	62 days	14	84	—	⅝ in.	1¼ in.	2⅝ in.	4·31	When the load was equal to 42 cwts.—half the ultimate load—a crack first appeared in the centre of the arch. This gradually increased until it was 5/16 in. wide on the underside before collapse.
U	2	21/1/96	6	6	3	0	3	5	1	2	1	½	24/3/96	63 ,,	—	—	—	—	—	—	—	Arch got damaged and could not be tested.
V	3	21/1/96	6	6	3	0	3	5	3	0	1	1⅙	24/3 96	63 ,,	10	60	¾ in.	1⅛ ,,	1 15/16 ,,	2¼ ,,	3·13	Cracked when ¼ breaking load was on.
W	4	21/1/96	3	6	2	0	3	3	1	2	1	½	24/3/96	63 ,,	24	144	1/16 ,,	⅛ ,,	¼ ,,	⅞ ,,	20·57	When ⅝ of the breaking load was on, the work was left and loading proceeded at 6.30 a.m. next day till the arch broke. It broke suddenly.
X	5	21/1/96	3	6	2	0	3	3	1	2	1	½	25/3/96	64 ,,	28	168	1/16 ,,	5/16 ,,	9/16 ,,	1 5/16 ,,	24·00	Broke gradually.
Y	6	21/1/96	3	6	2	0	3	3	3	0	1	1⅙	25/3/96	64 ,,	24	144	3/32 ,,	¼ ,,	½ ,,	1⅝ ,,	20·57	

Note—The average weight of rails is taken at 6 cwts. each.

APPENDIX.—Expanded Metal Company.—Experimental Concrete Slabs.—Specification for Concrete.—Report of Messrs. Fowler & Baker, dated April 29th, 1896.

QUALITY OF CONCRETE.

Portland Cement, 1. Clean-washed Fine Gravel, to pass through ¾ in. mesh, mixed with correct quantity of clean-washed sharp sand, 3.

(*a*) A vessel, whose exact cubical capacity is to be ascertained, to be filled first with the gravel to be used. The gravel to be first made quite dry. In preparing the gravel it is to be screened, so as to exclude the fine sand, say on a sieve twenty meshes to the inch. It is also to be screened to exclude the coarse gravel, say on a sieve with ¾ in. mesh.

The vessel so filled with the twice-screened dry material is to have clean fresh water poured into it, and the quantity so poured in to be accurately measured; it shall be poured from a graduated vessel. As much water is to be poured in as will completely fill all the interstices of the gravel, and until the water reaches the top of the vessel and runs over.

The volume of water so ascertained shall then represent the quantity of cement and sand to be added to the gravel to make the concrete. As the concrete is to be in the proportion of one of cement to three of aggregate, the relative quantities of cement and sand will then be arrived at.

Should it be found that a true proportion of three to one cannot thus be arrived at, the screening of the gravel must be done upon a sieve with ten meshes to the inch, and anything that is retained on such a sieve and passed through one with ¾ in. mesh shall be called "gravel," and then treated as before described, in order to arrive at the necessary quantities of sand and cement.

(*b*) Having determined the correct quantities of cement, sand and gravel, accurate measures are to be made to correspond to these proportions, so that each mixing of concrete shall be done in exactly the same way.

(*c*) An experimental mixing of concrete must be made to determine the proper proportion of water to be used. Probably one-sixth of the volume of the dry material, when the proportion is three to one, will be found about a correct quantity, but whatever it is, the concrete, after being turned over three times after admixture of water, must not be in a wet sloppy condition, but must be fairly dry. The most suitable quantity of water having thus been ascertained, a proper vessel must be marked to contain this amount, and with each mixing of concrete the water must be measured as well as the dry materials.

(*d*) The sand and gravel having been washed, if necessary, are to be measured in their respective gauge boxes and placed upon a clean wooden floor and incorporated together. The cement is then to be gauged and placed upon the top of the heap of sand and gravel. Two men are then to turn it over by hand, standing on opposite sides of the heap and allowing their shovels to meet in the centre. The mixture in this way is to be turned over three times while dry. It is then to be formed into a ring, and half of the total quantity of water is to be placed in the centre. The material at the edges is to be turned into the centre, and then the remainder of the water is to be added.

The whole is now to be turned over three times in the wet condition in a similar manner to that described for the dry.

The weight per cubic foot of the cement the gravel and the sand to be carefully ascertained.

The slabs are to be made in wooden frames, of which the inside faces are planed.

They are to be placed upon a planed wood floor, and all surfaces that come in contact with concrete are to be well brushed with oil to prevent sticking. In the case of the slabs made in combination with expanded metal, the metal is to be placed upon the wood floor inside the frames, and the first concrete put in is to be well worked with a trowel into the corners, so that a solid slab of the full dimensions throughout is obtained. The top surface of the slabs is not to be floated or plastered with a trowel, but is to be worked to as smooth a surface as possible with a metal-edged straight-edge worked across the edges of the frame. The concrete must not be mixed or the slabs made in frosty weather. After making, and after time has been allowed to set—say twenty-four hours in mild weather—the surface of all the slabs is to be covered with bagging of good thickness so that no frost can have access to it and destroy or damage the concrete. After three or four days, according to the weather, the wood frames may be taken off. The slabs are then to remain for two months—say nine weeks—from the time they were made, and are then to be tested.

TESTING.

At the expiration of nine weeks from the date of making, each slab is to be tested under an uniform load.

The 4 ft. slabs are to be placed upon a solid foundation, with a clear bearing of 3 ft. 6 in., and to be weighted with rails or other convenient loading until they break.

The 7 ft. slabs are to be similarly weighted and broken, but the clear span is to be 6 ft. 6 in.

CONCRETE ARCHES.

In addition to the slabs to be made and tested as before described, six concrete arches are to be made as follows, and tested in a similar way to destruction:—

(*a*) Two arches 3 ft. 6 in. clear span and 2 ft. wide, 3 in. thick at the centre, and of the form indicated and of the same concrete as specified for the slabs, 1 of cement to 3 of sand and gravel.

(*b*) Two arches 6 ft. 6 in. clear span and 3 ft. wide, 3 in. thick at the centre and of the form indicated, and of the same concrete as specified for the slabs, 1 of cement to 3 of sand and gravel.

(*c*) One arch 3 ft. 6 in. × 2 ft. wide and 3 in. thick, of concrete containing 3 of cement to 1 of sand.

(*d*) One arch 6 ft. 6 in. clear span and 3 ft. wide, 3 in. thick, of concrete containing 3 of cement to 1 of sand.

The arches to be properly and carefully formed upon wooden centres, and to have substantial abutments to take the thrust of the test load. They are to be protected from frost and finished and tested in a similar way and after the same period as the slabs already described.

The form of the arch is indicated on the attached sketch.

2, Queen Square Place,
Queen Anne's Mansions,
Westminster, S.W.
December, 1895.

Report of Test carried out by Messrs. Idris & Co., Ltd.

THE illustration represents an independent test carried out by the "Idris" Mineral Water Company, with a slab of concrete 7 feet long by 3 feet wide, 3 inches thick, composed of four parts of clinker to one part of Portland Cement, with Expanded Metal 3 inch mesh, $\frac{1}{4}$ inch by $\frac{1}{8}$ inch strands, embedded in its under surface. The slab is shown supported on timbers, giving a clear span of 5 feet, loaded with bricks, weighing about 10 tons or a distributed weight equivalent to about 13 cwt. to the square foot.

Expanded Metal was afterwards employed by this Company in the concrete floors of their new factories at Camden Town and Southampton, and from whom we received the following testimonial :—

PRATT STREET.
CAMDEN TOWN.
LONDON, N.W., *January 22nd*, 1898.
(BUILDING DEPARTMENT.)
[illegible]
SOUTHAMPTON & LIVERPOOL.

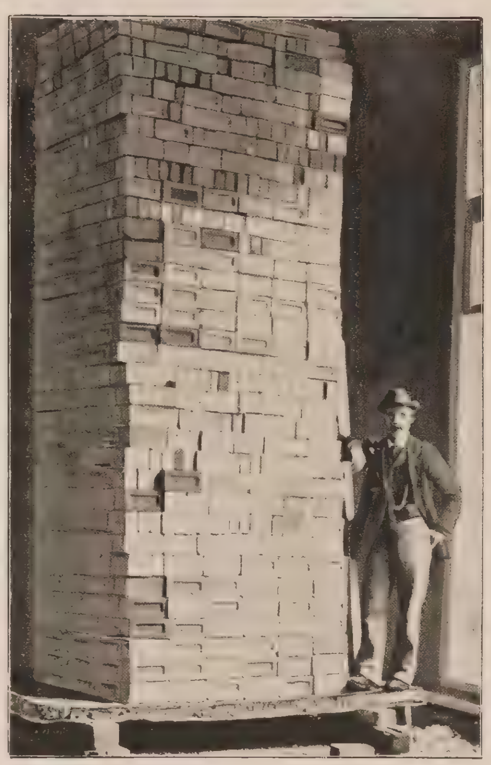
DEAR SIR,

We have no objection to your using or mentioning our name in connection with the test made by us. We are perfectly satisfied that it is a good thing, and are going on making floors in the same way here and at our Southampton Factory.

Yours faithfully,

(Signed) IDRIS & CO., LTD.

per T. H. W. IDRIS.



TESTING A 3IN. CONCRETE SLAB, CONTAINING EXPANDED METAL,
AT 5FT. CLEAR SPAN,
UNBROKEN WITH LOAD OF 13 CWT. TO SQUARE FOOT.

REPORT OF TESTS

made by

The Engineer-in-Chief of the New Birmingham Water Supply

(Mr. JAMES MANSERGH, M.I.C.E.).

Before Expanded Steel was used in the concrete walls of the new Birmingham Water Supply aqueducts, a series of crucial Tests were made by the Engineer-in-Chief, with the following results, which will speak for themselves:—

	Clear Span.	Breaking Load.			Maximum deflection at centre.
		Total.		Per sq. ft.	
SLABS WITHOUT EXPANDED METAL—		Tons.	cwts.	Cwts.	
A, uniformly loaded	6 ft. 9 in.	5	12	4·11	Not observed.
B, irregularly loaded	6 ft. 9 in.	6	13¼	4·935	Not observed.
SLABS WITH EXPANDED METAL—					
C, uniformly loaded	6 ft. 9 in.	26	13¼	19·75	½-an-inch.
D, irregularly loaded	6 ft. 9 in.	22	16¾	16·92	¾-of-an-inch.

The concrete in each case was in the proportion of 4 of broken rock (¾-in. gauge) and sand to 1 of Portland Cement.

The slabs were 7 ft. 6 in. long by 4 ft. wide, 6 in. thick, and when tested, the supports were 6 ft. 9 in. apart.

The unsupported area was, therefore, 27 square feet.

The age of all the slabs tested was 88 to 89 days.

The rails used for testing were 32 ft. long, weighing 56 lbs. per lin. yard.

The Expanded Steel used was 3 in. mesh, ¼in. by 3/16in. strand.

Test by the Northern Architectural Association, Newcastle-upon-Tyne.

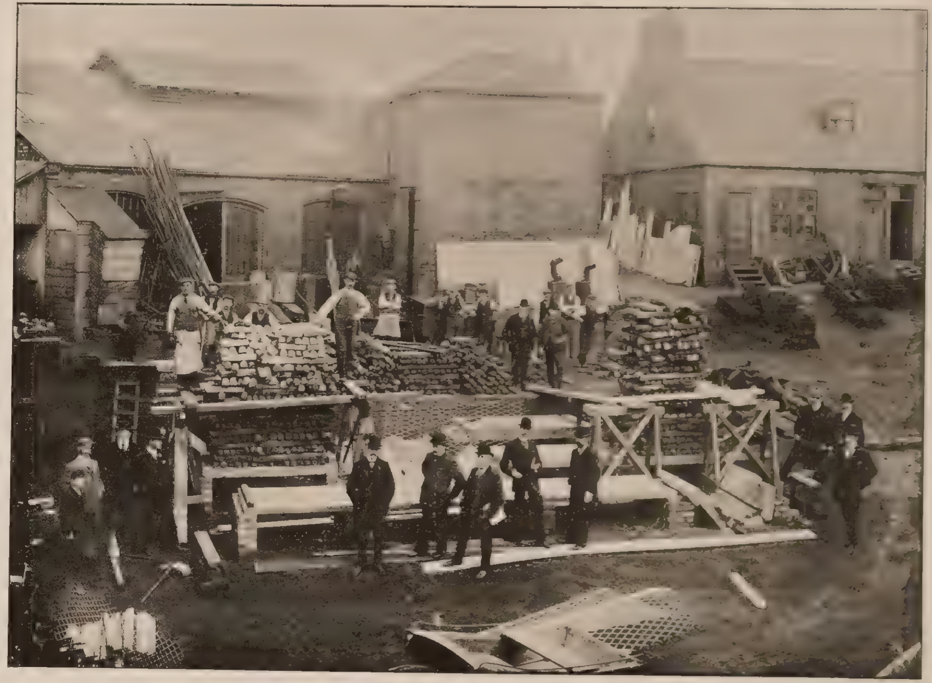
Concrete and Expanded Metal.

By A. C. Davis, F.C.S.

PROBABLY no constructional undertaking in the uses of expanded metal in concrete has been subjected to a more searching preliminary test than that before a select committee of the Northern Architectural Association (England), carried out recently in the foundry yard of the Gallowgate Ironworks.

The matter was taken in hand immediately after the destruction of a portion of the Elswick Works by fire, and it was understood that upon the finding of this committee, Mr. Frank Rich—the architect of Armstrong-Whitworth Company—would judge whether he should feel warranted or not in recommending the use of expanded metal in this connection to his principals—one of the largest and best known engineering firms in this country.

Twelve slabs of different sizes, ranging from eight to three inches in thickness, and from eight to five feet long by four feet wide, were cast in wooden boxes supported by brick piers, and the concrete mixed according to the specification of the sub-committee, the thicker slabs containing no expanded metal bond. Through causes which were individually remarked, although not officially reported upon as not coming within the scope of the object of these tests, a most surprising series of results were obtained—results so far in advance of the requirements or of any previous claims of this company with regard to the efficiency of expanded metal in concrete slabs, that to this day no special claims have been based upon them. The ordinary formulæ of the company, which have undergone little change since they were first compiled by those eminent engineers, Sir Benjamin Baker and Sir John Fowler, have always regarded the tension efficiency of a given beam to be increased from ten to twelve times by the use of an expanded metal tension bond, yet in this case, through the use of the ordinary Tyne ballast, which is commonly employed in the neighbourhood of Newcastle, of some possible eccentricity of the cement which was not gone into and possibly again the conditions under which the slabs set from the latter part of July until the 15th of the following November, the results were the most extraordinary ever experienced in the history of expanded metal, the heavy unarmoured slabs breaking under ridiculously small and inadequate loads, and those thin slabs contrasted with them, although much thinner and provided with expanded metal bonds, either sustaining their normal loads as might be looked for according to established formulæ, or, as in three cases, absolutely refusing to give way after they had been piled so high with pig iron that the loads of iron were in danger of toppling over upon the workmen, so that the tests had to be abandoned with the slabs yet unbroken. The result in some cases showed an increase in the efficiency of expanded metal slabs of over thirty times, as will be seen by a comparison of the figures of the official report, as follows:—



COMPARISON AND TESTING OF ARMOURED CEMENT WITH ORDINARY CEMENT.

No.	Expanded Metal.	Net Length.	Net Area Sq. Ft.	Thickness in Inches.	Concrete Proportions.	Breaking Weight.
1	None	8 ft.	28	8	5 to 1	9 cwt.
2	No. 10	8 ft.	28	5	5 to 1	237 cwt. 3 qrs. 14 lbs.
3	None	6 ft. 6 in.	22	8	5 to 1	22 cwt. [illegible] 18 lbs.
4	No. 10	6 ft. 6 in.	22	5	5 to 1	Unbroken.
5	None	8 ft.	28	4½	3 to 1	• Not recorded.
6	No. 8	8 ft.	28	3	3 to 1	96 cwt. 1 qr. 17 lbs.
7	None	5 ft.	16	8	5 to 1	124 cwt. 2 qrs. 20 lbs
8	No. 8	5 ft.	16	3	3 to 1	213 cwt. 3 qrs 8 lbs.
9	None	5 ft.	16	4½	3 to 1	10 cwt. 3 qrs. 10 lbs
10	No. 10	5 ft.	16	5	5 to 1	Unbroken.
11	None	6 ft. 6 in.	22	4½	3 to 1	17 cwt. 1 qr. 25 lbs.
12	No. 8.	6 ft. 6 in.	22	3	3 to 1	113 cwt. 0 qr. 22 lbs.

No. 1 broke before the test began, two men and six pigs of cast iron being on it, *i.e.*, about 9 cwt.

No. 2 shows about ¼ inch deflection under 75 cwt.; ½ inch deflection under 175 cwt., cracked at 220 cwt., and broke under a load of 237 cwt. 3 qrs. 14 lbs

No. 4 was unbroken under a load of 340 cwt. 1 qr. 21 lbs., when it was found inconvenient to pile the pig iron to a greater height. It showed $\frac{5}{8}$ inch deflection, but returned to nearly its original straightness when this load was removed.

No. 5 broke accidentally while the men were piling up the weight upon No. 4 slab.

No. 9. The cracks on this slab were in form as sketched.

No. 10 was unbroken with a load of 270 cwt. 2 qrs. 2 lbs., at which load the piling was 11 feet high. Under a load of 261 cwt. 2 qrs. 12 lbs. it indicated slight deflection, but returned

These results, however, coupled with the fact that in regular practice precautions would be taken to use a better class of aggregate and to ensure the careful inspection of all cement employed, left no doubt as to the superior merits of the system, and the Expanded Metal Company were commissioned to provide floors of sufficient strength to carry the lathes and other machinery for turning out the parts of the heaviest kinds of ordnance, etc., produced at the Armstrong-Whitworth factory

The first order which was carried out during the year 1900 was, as shown in the illustration, for [illegible] arched floors, of which the following is the formulæ:—Mains, 20-feet 6-inch centres; channels, 4-feet centres concrete, 4-to-1 clinker and Portland cement, 5 inches thick to carry 10 cwts. per super foot without deflection, and 20 cwts. without breaking. The whole area in question was 8,000 super yards

Following this came a repeat order for flooring to further shops, which has just been completed, the following being the formulæ Mains, 20-feet centres; channel 5-feet spans; concrete, 5 inches thick; expanded metal No. 10; safe working load, 5 cwts. per super foot; and mains, 20-feet centres; channels, 6-feet centres; concrete, 4½ inches thick; expanded metal, No. 8; safe working load, 2½ cwt. per super foot; the entire area in question being of 4,000 super yards.

The whole building was steel-framed structures, the flooring being 40 feet and 60 feet above the ground, carried on steel stanchions tied longitudinally with rolled steel joists at either side of the building, which is 40 feet wide.

The New Expanded Metal Company have reason to be particularly proud of this achievement, as not only in the satisfaction of so eminent an engineering firm, who, unlike most principals, were personally able to appreciate the splendid character of the work, but in having given satisfaction to Mr. Rich, who ranks among those who are absolutely at the head of the profession in the North of England.

To the Chairman and Directors of

THE NEW EXPANDED METAL COMPANY, LIMITED,
York Mansion, Westminster,
S.W.

Experimental Test made at Glasgow on an Expanded Steel Concrete Slab.

Gentlemen,

A test was completed at Messrs. Connal's Pig Iron Stores, off Paisley Road West, Glasgow, on Tuesday the 20th January, 1903, upon a slab of concrete 7 inches in thickness, containing a tension bond of one layer of No. 10 3 inch mesh, ¼ inch by $\frac{3}{16}$ inch (bare) strands Expanded Steel, laid horizontally, at a level sufficient to provide cover, near its underside. The slab, which had been constructed on August 2nd, 1902, had its temporary centering struck on September 2nd, 1902, and had been loaded with a provisional evenly distributed load of 3 cwts. to the super. foot on November 12th, 1902, this load having remained upon the slab until the 20th inst., and was supported upon dwarf walls 3 feet in height. It was composed of concrete consisting of one part of best Portland cement, together with about 2½ parts of brick broken to pass a ¾ inch mesh sieve, and 1½ parts of clean sharp sand, all obtained in the neighbourhood of the test, in the ordinary way.

The slab had a bearing of 6 inches on all four sides, the unsupported area of the slab being 15 feet by 15 feet.

The undersigned formed an Inspection Committee, and the test of the slab to destruction was executed in their presence, in addition to the proceedings being witnessed by a large number of architects, engineers and contractors, who had been invited to be present.

Prior to the proceedings, the Committee pointed out to Mr. F. Purton (your Manager), on the morning of the 20th inst., that the slab to be experimented upon was in a sound condition, had not deflected at all under the super imposed load of 3 cwts. per square foot, and that the bearings were in good condition and level all round.

The test to destruction was executed by the gradual application of pigs of iron carefully laid upon the unsupported area of the slab, that is to say, clear of the supporting walls, and the slab finally gave way under a total load of 56 tons 11 cwts., the fractures radiating from the centre to the angles of the square.

At the conclusion of the test, the Committee agreed that the footings of the walls had not in any way subsided, shewing that the test upon the suspended slab had not been influenced in any way by adverse conduct of the walls.

The test is highly satisfactory, in that it proves that the formula your Engineers have heretofore used for spans constructed with Expanded Steel cut by your old machines (that is to say, spans up to 8 feet), may be safely applied to the wider spans that may be constructed with sheets cut by your new machines (that is to say, up to 16 feet).

The Committee desire to point out that the slab formed a good example of an ordinary marketable floor, there being nothing extraordinary either about the materials used, or its construction, therefore any ordinary contractor could undertake and execute similar work with equally satisfactory results, and hence the breaking load (which works out at 5 cwts. per foot super), may be accepted as reliable data; and, allowing a factor of safety of 4, gives a safe working load of 1¼ cwts. per foot super.

This strength is in excess of the ordinary requirements for a crowd load of people, which according to some authorities may average as much as 120 lbs. per square foot for dense crowds; but of course, it is not in excess of the loads required for heavy warehouse floors, which your Engineers would design according to the circumstances of special loads requiring to be dealt with.

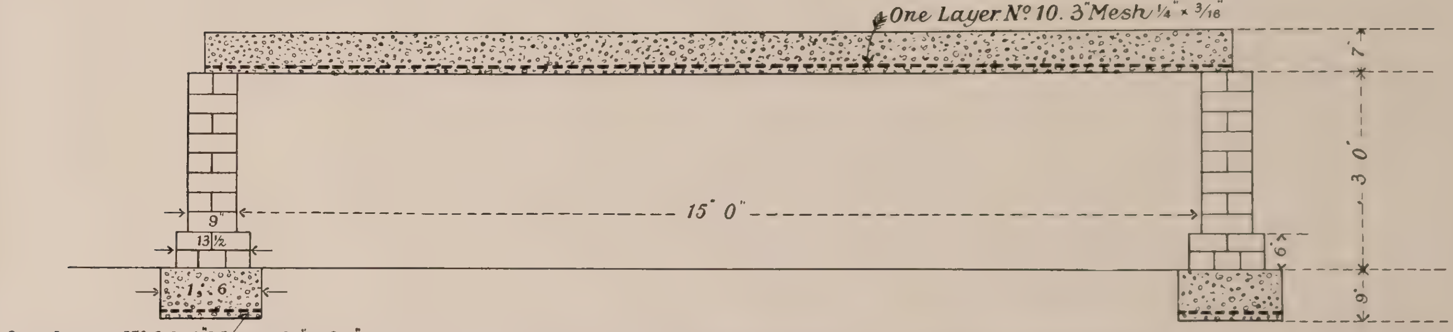
Your obedient Servants,

(Signed) A. T. WALMISLEY, M. Inst. C.E.
J. P. ALLEN, P.A.S.I.
AND. HOME MORTON, Assoc. M. Inst. C.E.

January 26th, 1903.

EXPANDED STEEL AND CONCRETE SLAB 15'-0" CLEAR SPAN WITH 6" BEARING ALL ROUND.

SCALE ½"=1'-0".


One Layer No. 10. 3" Mesh ¼" × 3/16"
7"
3' 0"
9"
15' 0"
13½
6"
1' 6"
9"
One Layer No 30 3" Mesh 3/8" × 3/16"

SECTION BOTH WAYS BUT ONE OPENING IN EACH OF TWO WALLS.

CONCRETE.—All concrete to be about 2½ parts ¾" mesh broken brick, 1½ parts clean sharp sand, and 1 part best Portland Cement.

OFFICIAL REPORTS

OF THE

BRITISH FIRE PREVENTION COMMITTEE.

[*Founded 1897.—Incorporated 1899.*]

FIRE TEST No. 1.—February 15th, 1899.

A FLOOR BY

THE EXPANDED METAL COMPANY, Ltd., London.

Object of Test.

TO record the effect of a smouldering fire of fifteen minutes duration, of a temperature not exceeding 600° Fahr., followed by a fierce fire of one hour, gradually increasing to a temperature of 2,000° Fahr., followed suddenly by the application for three minutes of a stream of water, and the consequent rapid cooling.

NOTE: The area of the floor under investigation was to be 100 feet superficial in the clear (10 ft. × 10 ft.).

The floor was to be loaded with 140 lbs. per square foot.

The time allowed for the construction and drying of floor was to be three months (winter).

Summary of Effect.

THE plaster ceiling below the floor remained intact until the application of water.

There was a slight deflection of floor and ceiling.

The concrete of floor was slightly and superficially cracked.

The fire did not pass through the floor.

Description of Testing Plant.

(See Figs. 1 to 4.)

THE Testing Chamber used was located at the Committee's Testing Station, and was known as "No. 1 Hut."

The chamber was constructed, as shown, of stock bricks, with lime mortar, and measured 10 ft. by 10 ft. internally.

The ceiling of the floor tested was 7 ft. 6 in. above the pavement of the chamber.

The hut was roofed in with galvanized iron.

The door-opening on the south side measured 2 ft. 6 in. by 6 ft. 6 in., and was closed by an iron sheathed wooden door.

The fuel used was gas produced at the station, and the supply was regulated by valves and dampers.

The gas was admitted through two mixing chambers of fire-brick, each 10 ft. by 3 ft. super, as shown.

Two Robert-Austen pyrometers were used for recording temperatures, the first to take a continuous record from point 1A, and the second to take four observation records from points 1, 2, 3, 4.

The load was of pig iron distributed evenly on the surface of the floor.

There were two observation holes in the north wall and one in the door.

The ventilation holes were in the east and west walls.

The photographs were partly taken by daylight and partly by flash light.

The stream of water was applied through a branch with $\frac{1}{2}$ in. nozzle equipped with a pressure gauge, and supplied from a manual fire engine similarly equipped.

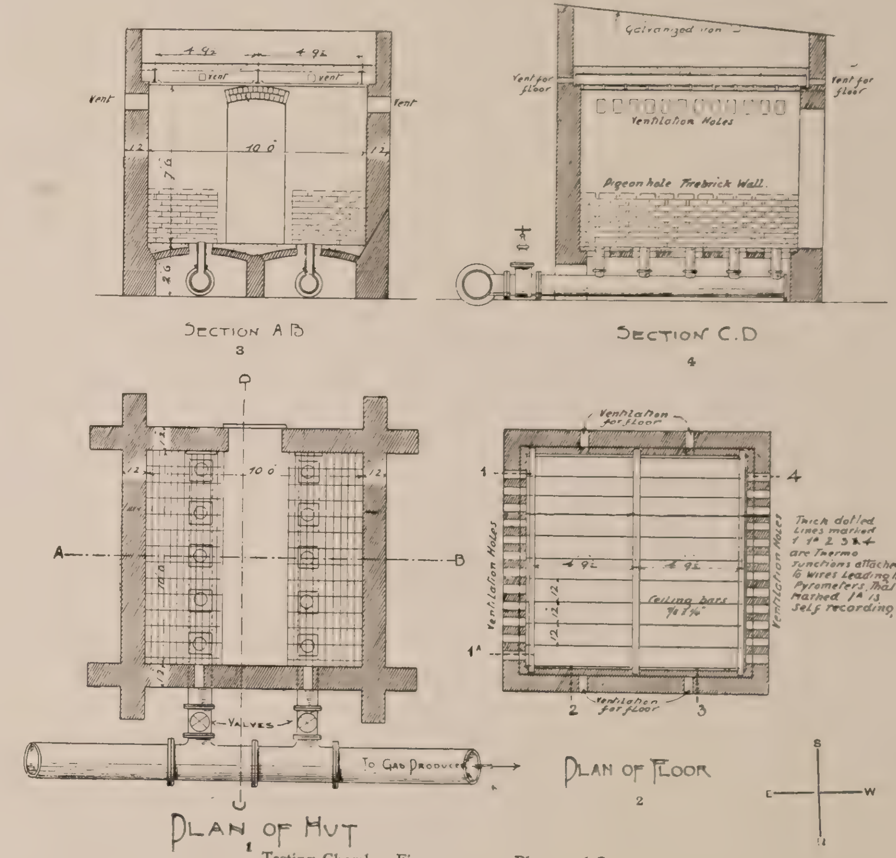
Construction of the Floor.

(See Figs. 1 to 7.)

A PLAN, two sections, and some details of the floor are shown. The erection of the floor was as follows:—

On November 14th, 1898, three rolled steel joists, 6 in. deep, 3 in. wide, 14 lb. per foot, were put across the chamber. They ran north to south, and rested on the $4\frac{1}{2}$ in. set off. The two outer joists were placed 1 in. from the east and west walls respectively, and the third was placed in the centre, making the distance between the centres of the three joists 4 ft. $9\frac{1}{2}$ in. Provision for air was made by cutting four holes 4 in. by 4 in. between the floor and ceiling in the exterior walls. These are marked "Ventilation for Floor" in Figs. 2, 3 and 4.

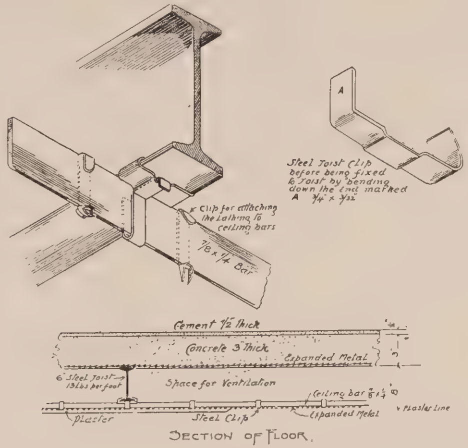
On November 16th, three wooden bearers were put up in each bay, 3 ft. 4 in. centre to centre, by 6 in. deep, 2 in. thick, and covered with 1 in. boarding, as centering. On the top of the centering and covering three-quarters of the entire surface of the floor expanded metal was laid, of the kind known as 3 in. mesh, $\frac{1}{4}$ in. by $\frac{1}{8}$ in. strand, at the centre the metal overlapped 18 in. At the north-east corner a quarter of the area was covered with $\frac{1}{4}$ in. by $\frac{3}{16}$ in. metal, same mesh as before.



Testing Chamber, Figs. 1, 2, 3, 4. Plans and Sections.

Interior of Chamber, Fig. 10. General View.

On November 16th, the concrete floor was put in. The cement used was Portland and was furnished by William Lee, Son & Co., of London. It was not specially selected for this test, but was delivered in the ordinary course of business. The furnace ash (or cinder) came from Gas Works at Bank Hall. One cubic yard of furnace ash (or cinder) broken up small enough to pass through 1½ in. ring was placed on a platform, prepared for the purpose, and then covered with four sacks of cement, each sack containing two bushels. The material was turned over three times dry. The concrete was then divided into four equal parts for convenience of mixing, and one part mixed at a time. The quantity of water used was 58·18 gallons for the whole, and the concrete was well mixed. The concrete was then carried in pails on to the centering and laid over the entire surface, great care being taken to have the meshes of metal well filled. The concrete was trodden down or beaten with the flat side of an ordinary shovel. The concrete was put in 3 in. thick.


Clip for attaching the Lathing to ceiling bars
7/8 x 1/4 Bar
A
Steel Joist Clip before being fixed to Joist by bending down the end marked A 3/4" x 3/32"
Cement 1/2" thick
Concrete 3" thick
Expanded Metal
3"
6" Steel Joist 13 lbs per foot
Space for Ventilation
Ceiling bar 7/8 x 1/4
Plaster Line
Plaster
Steel Clip
Expanded Metal
SECTION OF FLOOR.

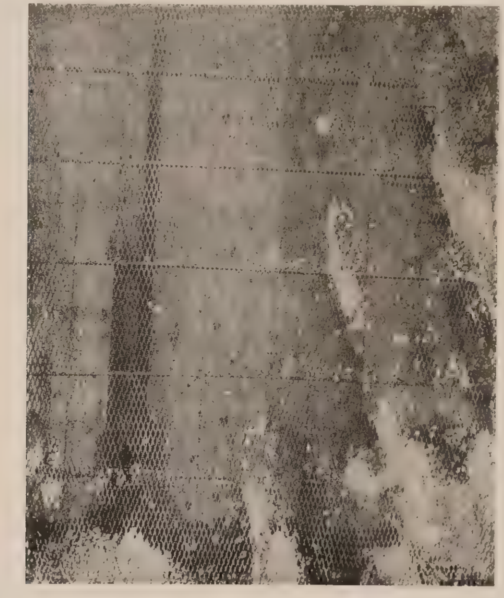
The Floor, Figs. 5, 6, 7, Details. *Sketch not to scale.*

On the same day (November 16th), while the concrete was still damp, one half of its upper surface (west side) was covered with ½ in. cement and sand in equal proportions, similar cement being used as for the concrete. The sand was good sharp unwashed pit sand. On the following day (November 17th) the remaining half of the floor (east side) was covered, the same proportions of cement and sand being used. The total thickness of concrete and cement was 3½ in.

On November 28th the centering was taken down.

On November 30th the expanded metal for the ceiling was put up. Bars ⅞ in. by ¼ in. thick were placed at right angles to and below the joists, 12 in. centre to centre, supported by steel clips 3/32 in. thick by ¾ in. wide which were secured to bottom flanges of the joists. The expanded metal was then secured to bars with steel clips. The metal lathing used for the ceiling is known as ⅜ in. mesh, 3/32 in. deep in Strand, Siemens-Martin steel.

On December 5th the ceiling was plastered with coarse stuff, ½-in. thick, below the expanded metal, the materials being mixed in the proportion of 1 of lime to 2 of sand with about 1 lb. of dry, long, well-beaten hair to every 3 cubic feet of coarse stuff, the coarse stuff being brought ready mixed on to the ground.



The Floor, Fig. 8. View after Test, taken from below.

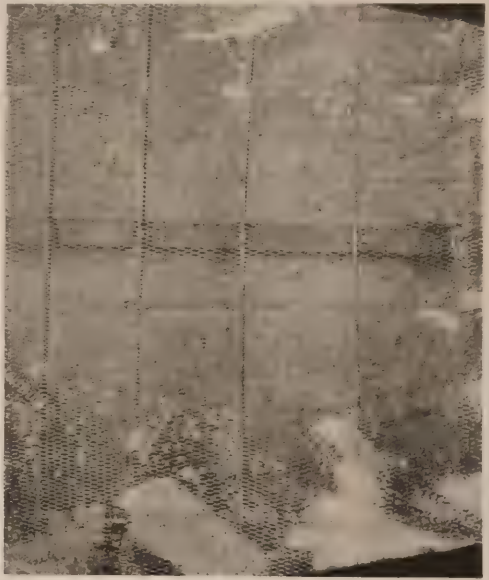
The weather report during building operations was "unsettled with rain." On the days on which the concrete was laid and the ceiling plastered, *i.e.*, November 16th, 17th, and December 5th, the weather was fair, the temperatures being respectively 48°, 50°, and 55° Fahr.

On December 6th, the floor having been completed, the roof was put on.

From December 6th, 1898, until February 14th, 1899, the floor remained with door and all ventilation holes open.

In December the weather was unsettled with rain and gales. The rainfall for the month (taken at Camden Square) was 2·54 inches, with a maximum of ·87 on December 6th. The maximum temperature was 57·1° Fahr., and the minimum 27·1° Fahr. The number of nights with a temperature below 32° Fahr. was three.

On December 27th (evening), during a violent gale, the roof of the hut was blown off and the floor flooded with rain. The roof remained off until the morning of December 28th, when it was re-fixed. It was found that the water had soaked through the floor and ceiling, making the ceiling very wet. From the 28th December, 1898, to January 3rd, 1899, the weather was very stormy and wet. No artificial drying was employed.



The Floor, Fig. 9. View after Test, Taken from below.

In January, 1899, the weather was unsettled with rain and gales. The rainfall for the month was 2·52 inches with a maximum of ·46 on January 15th. The maximum temperature was 56·2° Fahr., and the minimum 28·1° Fahr. The number of nights with a temperature below 32° Fahr. was six.

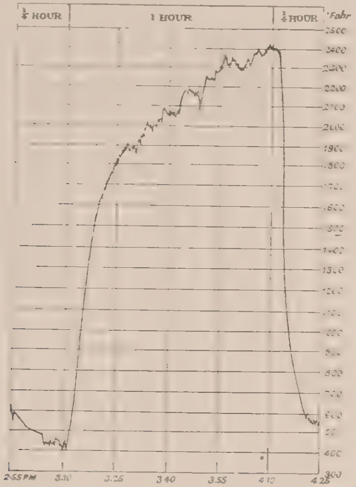
In February the weather was unsettled with rain.

Note: The records as to rainfall and temperature from 1st to 14th of February were not forthcoming on issue of this report.

On February 14th, the gas was lighted in the hut at 1-30 p.m. and kept very low until the test began. The roof was removed in the afternoon. The floor was loaded with pig-iron, equal to an evenly distributed load over the entire floor of 140 lbs. per square foot.

The Test.

On February 15th the test was undertaken. The following is the Log of the Test:—



At 2.40 p.m. the floor and ceiling were intact.

At 2.45 p.m. the door was placed in position, closed, and sealed with fire-clay, the observation hole in it alone remaining moveable.

At 3 p.m. the meteorological observations, taken at the Botanic Gardens, Regent's Park, read as follows:—State of weather, overcast; Rain, none; Wind, S.S.E.; Barometer, 29·76 inches; Attached Thermometer, 50° Fahr.; Dry bulb, 55·5° Fahr.; Wet bulb, 46° Fahr. NOTE: Rain fell slightly for a few minutes about. 3.45 p.m.

PRELIMINARY QUARTER-OF-AN-HOUR.

2.55 *p.m.*—3.10 *p.m.*

At 2.55 p.m. the gas was gradually turned on, and the temperature raised between 400° and 600° Fahr., as shown automatically per diagram on the continuous recorder (pyrometer point 1A).

THE HOUR.

3.10 *p.m.*—4.10 *p.m.*

From 3.10 to 4.10 the gas was further turned on and the temperature raised, as shown on the table below, the observations being taken at the four pyrometer points, Nos. 1, 2, 3, 4, and as shown automatically, per diagram, giving the continuous record from pyrometer point 1A.

OBSERVATIONS TAKEN AT POINTS NOS. 1, 2, 3, 4.

From 3 10 *p.m. to* 4.10 *p.m.*

TIME.	No. 1.	No. 2.	No. 3.	No. 4.
3.13 p.m.	530° Fah.	700° Fah.	800° Fah.	900° Fah.
3.18 ”	960° ”	1,220° ”	1,230° ”	1,080° ”
3.22 ”	1,240° ”	1,510° ”	1,560° ”	1,210° ”
3.25 ”	1,290° ”	1,560° ”	1,610° ”	1,400° ”
3.30 ”	1,460° ”	1,610° ”	1,720° ”	1,450° ”
3.35 ”	1,590° ”	1,690° ”	1,740° ”	1,520° ”
3.40 ”	1,650° ”	1,740° ”	1,740° ”	1,560° ”
3.45 ”	1,780° ”	1,810° ”	1,830° ”	1,660° ”
3.50 ”	1,780° ”	1,850° ”	1,880° ”	1,690° ”
3.55 ”	1,830° ”	1,930° ”	1,930° ”	1,780° ”
4.00 ”	1,870° ”	1,900° ”	1,920° ”	1,790° ”
4.05 ”	1,940° ”	1,960° ”	2,200° ”	1,870° ”
4.10 ”	1,960° ”	2,045° ”	2,090° ”	1,940° ”

At 3.25 p.m., vesiculated water vapour from the evaporation of water remaining in the concrete commenced to rise from above the concrete on the south side.

At 3.55 p.m. evaporation showed itself strongly from all over the floor.

From 3.10 to 4.10 p.m., at ten minutes interval, the surface of the ceiling was viewed from the observation-hole. No change in the floor or its ceiling was observed.

At 4.10 p.m. the gas was shut down and the door opened. The ceiling was intact. A slight deflection of the soffit was observed.

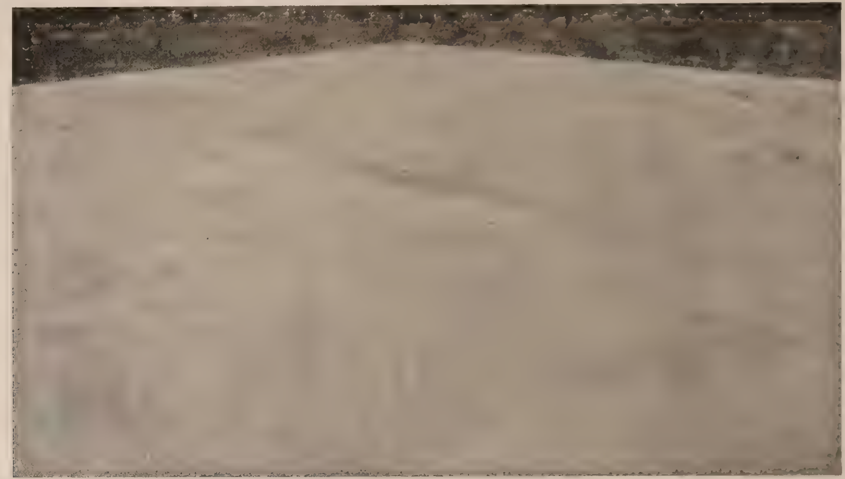
CONCLUDING QUARTER-OF-AN-HOUR.

From 4.10 *p.m. to* 4.25 *p.m.*

From 4.13 to 4.16 p.m., a jet of water was applied, the pressure ranging from 40 to 20 lbs., gradually decreasing.

On application of water to the ceiling, the portion of the plaster struck immediately fell down—the portions not touched remained in position.

From 4.10 to 4.25 p.m. the temperature rapidly decreased, as shown on table herewith, and also on the diagram of the continuous record.



The Floor, Fig. 11. View after Test, taken from above.

OBSERVATIONS TAKEN AT POINTS No. 1, 2, 3, 4.

From 4.10 p.m. to 4.25 p.m.

TIME.	No. 1.	No. 2.	No. 3.	No. 4.
4.12 p.m.	1,900° Fah.	1,850° Fah.	1,800° Fah.	1,680° Fah.
4.14 ,,	1,410° ,,	130° ,,	980° ,,	1,130° ,,
4.16 ,,	1,050° ,,	60° ,,	550° ,,	880° ,,
4.18 ,,	840° ,,	100° ,,	410° ,,	790° ,,
4.20 ,,	760° ,,	220° ,,	380° ,,	720° ,,
4.22 ,,	700° ,,	350° ,,	370° ,,	680° ,,
4.24 ,,	650° ,,	390° ,,	380° ,,	630° ,,

At 4.25 p.m. the test was closed. The floor, excepting for the plaster referred to, remaining intact.

Observations after Test.

See Figs. 8 to 11.

On February 16th two photographs were taken of the floor from below, as shown herewith. Some fine cracks in the underside of the concrete are observable from these.

On February 16th the deflection of the centre joist was measured and found to be 1$\frac{3}{8}$ in. at centre of joist. The eastern joist was deflected $\frac{5}{16}$ in. at centre. The western joist was not affected.

On February 21st the iron load was removed. Some fine cracks were observed in the cement surface of the floor. They did not penetrate the coating of cement.

On February 23rd a general photograph of the ceiling was taken from below, as shown herewith, and likewise a photograph of the floor from above.

On February 24th the floor was further examined, and it was found that the fire had not penetrated the floor at any point.

No further observations were made.

General Arrangements.

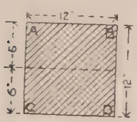
The Test was carried out in accordance with the procedure laid down by the Executive for investigations of this description, and conducted by a Sub-Committee of the Executive.

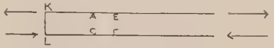
Extract from Paper read on September 7th, 1900, by Mr. A. T. WALMISLEY, M.I.C.E., before the British Association at Bradford.

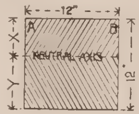
The use of . . . Expanded Steel in Concrete . . .

THE subject of the judicious introduction of iron and steel sections as a tensile element in the construction of concrete beams and slabs is one which at the present time is very much engaging the attention of engineers. . . .

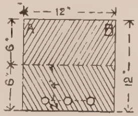
At first the use of expanded metal was restricted almost wholly to lathing for plastering, in which, as stated upon the makers' catalogues, "the key is the thing," but as the machinery for its development has been improved, it has become recognised as an effective binder for heavy floors, canal walls, docks, locks and reservoirs, as well as for reclamation walls facing the sea in sheltered positions. The concrete is entangled in the meshes, and continuity of the metal work throughout can be secured by slightly overlapping the sheets. Uniform distribution of strength combined with an effective keyage is also provided, and it needs no special supervision, as when independent rods or plates are introduced, to place the lattice work horizontally in a correct position in the concrete, but as regards its position vertically in the section, we may now profitably consider its effect. In order to appreciate the superiority of expanded metal in affording ample without extravagant iron or steel tensile aid to a slab of concrete, let us, for the sake of argument, calculate a concrete beam 12 ins. square in transverse section, assuming the neutral axis first of all to pass, if possible, through the centre of gravity of the section. If the beam be supported at both ends of its length, and loaded between the supports, the upper portion will be in compression and the lower portion in tension. The stress will be nil at the neutral axis, and a maximum along the outside top and bottom edges. The safe compressive working maximum stress may be taken approximately at, say, 400 lbs. per square inch, while the corresponding safe tensile maximum working stress would then, according to accepted data, be only 40 lbs. per square inch. Thus it will be seen that, with a central neutral axis, the beam would theoretically fail in tension long before the compression became prejudicially affected. This tendency to fail in tension would, however, be partially resisted by the fact that, practically, a flat arch is formed within the beam, which would appear to create the conversion of a large part of the vertical pressure into lateral thrust, but which really causes the section to act as a bar with a hollow curved soffit; and it is evident that the neutral axis under the influence of such a load would not remain coincident with the centre of gravity of the section, but would rise above it, until the tensile and compressive resistances were equal, so that the equilibrium of any short length of the beam resulted in a couple. Thus, if the panel A E F C is pushed towards the left by a force uniformly applied along a short margin, A E, at its upper section, its lower section, C F, will be thrust towards the right with an equal force, as represented in direction by the arrows, or vice versa. This couple, or pair of contrary forces, if acting alone, would exert upon the panel, A E F C, a rotating tendency; but we have the vertical effects of the reaction at the supports, K L, together with the action of the weight intervening between the support and the panel under consideration, K A C L each exercising their influence in the balance of moments round a turning point. The mean stress which can be applied upon the upper portion of the beam $\frac{400+0}{2}=200$ lbs. per square inch, and that upon the lower portion $\frac{0+40}{2}=20$ lbs. per square inch. In each case the resistance will be the mean stress of the area influenced, multiplied by two-thirds of the depth of the portion so influenced, which we have under consideration, that being the distance of the centres of pressure of the upper and lower portions above and below the neutral axis. Let X and Y represent respectively the depths of the top and bottom outside surfaces from the neutral axis. Then the resistance of the upper part in compression will be $200\times(12\times X)\times\frac{2}{3}X=1{,}600\ X^2$ inch-pounds. And the resistance of the lower part in tension will be $20\times(12\times Y)\times\frac{2}{3}\ Y=160\ Y^2$ inch-pounds. If these are equal then $1{,}600\ X^2=160Y^2$, or $10\ X^2=Y^2$. But $X+Y=12$, $\therefore X+X\sqrt{10}=12$ and $X=\frac{12}{4\cdot16}=2\cdot88$ and $Y=(12-2\cdot88)=9\cdot12$. The limit of capability is, therefore, not a compression of 200 × (12in. × 6in.) × 4in. = 57,600 inch-pounds, but 200 × (12 × 2·88) × ⅔ (2·88) = 13,271 inch-pounds. This divides the depth in the proportion of 24 to 76, instead of two halves, and gives the percentage.



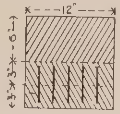




We will now consider the effect of introducing three tension rods in the lower portion of the beam. To maintain the neutral axis in the centre of the section the quantity of iron with a unit stress of five tons to the square inch needed to furnish the required balance of resistance would be, if applied at the centre of pressure $\frac{57{,}600-5{,}760}{5\times2{,}240\times4}=\frac{51{,}840}{44{,}800}=1\cdot15$ square in. as the quantity of iron needed to furnish the required resistance. Assuming three rods of $\frac{11}{16}$ in. diameter, equal to three times an area of ·37 square in., we have the requirement approximately attained. The chief requisite in construction is to provide sufficient cover underneath the iron to protect it from the action of fire. Should these rods be only embedded 1½ in. (centres) above the lower edge, C D, then their distance from a central neutral axis would be 4½ in., and their diameter would be $\frac{51{,}840}{d^2\times3\times\cdot7{,}854\times5\times2{,}240\times4\frac{1}{2}}=\frac{51{,}840}{151{,}200\ (\cdot7{,}854)\ d^2}=\frac{\cdot43}{d}$, or $d=\frac{11}{16}$ in. approximately, the same as before, although, theoretically, each rod would need 16 per cent. less sectional area than when placed ½ in. nearer the neutral axis.

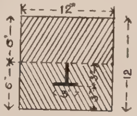


Let us next consider the insertion of 4 in. × $\frac{1}{16}$ in. wrought-iron plates, with ¼-in. cross rods and symmetrically disposed in the centre of the lower half, 2 in. apart, five in number. This gives us 5 (4 in. — ¼ in.) × $\frac{1}{16}$ in. = $\frac{75}{64}$ square inches = 1·7 square inches, and $\frac{75}{64}$ square inches × 5 tons (2,240) × $3\frac{2}{3}$ = 43,125 inch-pounds, and concrete (12 in. — $\frac{5}{16}$ in.) = $11\frac{11}{16}$ in. × 6 in. × 20 × 4 = 5,610 inch-pounds; total, 43,125 + 5,610 = 48,735 inch-pounds, so that in this case the neutral axis would become slightly raised above the centre line in order so to increase 48,735 inch-pounds, the tensile element, and to decrease 57,600 inch-pounds, the compressive element, until they form a couple that would produce equilibrium.



To avoid the expense of drilling or of punching the holes for the interlacing rod, Messrs. Lindsay & Co. in their system introduce alternate rods passing over and under the sections of iron or steel, arranged in pairs, thus saving the consequent weakening of the section, and in large floors these rods maintain light rolled joists in position placed a good distance apart.

If instead of vertical plates as above we next consider an inverted tee section 3 in. × 3 in. × ½ in. inserted with the top of the metal web touching the neutral axis, we have then from the iron section, first, the stress at the junction of the web with the flange as follows: $=\frac{2\frac{1}{2}}{3}$ or $\frac{5}{6}$ of 5 tons = 9,333·3 lbs.; web 2½ in. × ½ in. × $\left(\frac{0+9{,}333\cdot3}{2}\right)$ × ⅔ (2½ in.) = 9,722 inch-pounds; flange 3 in × ½ × $\left(\frac{9{,}333\cdot3+11{,}200}{2}\right)$ × 2·8 = 43,120 inch-pounds, giving a total of 52,842.

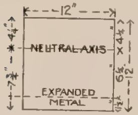


The area of cross section of tee iron = 2·75 square inches, and the area of concrete below the neutral axis — (72—2·75) = 69·25 square inches, and 69·25 square inches × 20 lbs. × 4 in. = 5,540 inch-pounds, and 52,842 + 5,540 = 58,382 inch-pounds. Supposing the compression of the upper portion above the neutral axis to balance this amount we should have $\frac{58{,}382}{(12\times6)\times4}=202\cdot8$ lbs. per square inch as the working unit stress above the neutral axis, or practically a stress of 200 lbs. per square inch as above assumed.

Lightness, combined with stiffness, may be attained in heavy floors by introducing the tubular system into the compressive element of the concrete, whereby the upper thickness can be placed at a comparatively greater distance from the neutral axis, the increased depth of the beam so attained, supported at both ends, tending to obviate deflection, but the alternative system of introducing hollow lintels below the neutral axis when the upper half depth is covered with solid concrete is unscientific, as it increases the area of the portion subject to compression, while reducing the area of the portion subject to tension, without con-

Extract from Paper by Mr. A. T. WALMISLEY, M.I.C.E.—(*continued*).

tributing thereto by the aid of metal. It will be seen that the insertion of wires or rods or bars or other separate sections contributes strength in the direction of length in which they are placed, but are evidently weak transversely, leaving the intermediate concrete unaided. Expanded metal, however, contributes strength laterally as well as longitudinally. It also provides keyage by its depth. The advantage gained by the lattice shape of the metal, prevents a continuous line of stress as obtained in systems in which the stress is mainly given in one direction only, so that with the use of a diamond-shape plate with open centres we have to allow a factor approximately of 2 to compensate for the angle of stress in its weakest direction. Thus, assuming so low a stress as 5 tons to the square inch in order to harmonise with the low units taken in the above calculations, we have $\frac{5 \text{ tons} \times 2{,}240}{2} = 5{,}600$ lbs. per square inch, and supposing we employ expanded metal to "size No. 10a," having a 3-in. mesh with strands ⅜ in. by $\frac{3}{16}$ in., *i.e.*, $\frac{3}{16}$ in. thickness by ⅜ in. width of plate we obtain in a width of 1 ft. run, a transverse section of $4\ (\frac{3}{8} \times \frac{3}{16}) \times 2 = \frac{9}{16}$ square inch, capable of sustaining as expanded metal a safe stress in any direction of $\frac{9}{16} \times 5{,}600 = 3{,}150$ lbs., which, if laid 1½ in. above the under surface of the beam, or 6¼ in. below the neutral axis (as sketched in the accompanying section) would provide a moment of resistance of 19,687 inch-pounds, which added to concrete (12 in. × 7¾ in.) below the neutral axis = 93 square inches × 20 lbs. × ⅔ (7¾ in.) = 9,610 inch-pounds, giving a total tensile resistance of 29,297 inch-pounds, so that in the portion above the neutral axis we have a unit working stress in compression to balance this amount of $\frac{29{,}297}{(12 \times 4\frac{1}{4}) \times \frac{2}{3}\,(4\frac{1}{4})} = \frac{58{,}594}{289}$ 203 lbs. per square inch, or practically 200 lbs. per square inch as the mean compressive unit strength. The consideration of beams of greater width than 1 ft. would result in the same decision, as the expanded metal would be uniformly increased in width with the concrete.



The present machinery at work at West Hartlepool is limited to sheets of 8 ft. in length, but larger machines are in contemplation to enable sheets of wider areas to be supplied. In order to maintain a definite distribution of the character of the stress, the author considers that all slabs of concrete in which metal is embedded below the neutral axis should not be fixed at the supports, but merely rest free on proper bearings. The units assumed in the preceding cases under review in this paper may be deemed to be over-cautious. Of course, the use of steel having now supplemented iron for such purposes, a unit stress of 6½ tons per square inch may be taken. This, if anything, is, however, an additional argument in favour of the use of expanded metal, as the employment of other sections is seen to be in excess of requirements, whereas an expanded metal section gives sufficient but less sectional areas than in the other calculations. With an increased unit stress it is evident the moment of resistance contributed by the steel embedded in the section would bring down the neutral axis nearer to the level of the position of the centre of gravity, and hence under those considerations would increase the area available to resist compression. It will be observed that independently of facility of construction and uniform distribution of tensile resistance, the use of even a heavy section of expanded metal gives only 49 per cent. of the metal introduced with iron wires or bars, and about 20 per cent. of a tee-iron section.

In another test made by the Expanded Metal Company in May, 1900, upon a slab 12 ft 6 in. by 11 ft. clear span, 5 in. thick, composed of 4 parts of fine clinker to 1 of Portland cement, with expanded metal embedded in the under surface, the expanded metal was 3 in. mesh, ¼ in. by $\frac{3}{16}$ in. strands, and was in four sheets, which were laid on the temporary centreing with a 12 in. lap, and the meshes overlapping were clipped together with steel clips. After the concrete was set and the centreing removed, the expanded metal was completely hidden in the under side of the concrete. The slab was allowed to remain for seven weeks, and was supported with a 3 in. bearing on its four sides on a timber sole plate. Thames ballast was thrown upon the slab in quantities of a cubic yard at a time, uniformly distributed until the load amounted to 35 tons, with slab supported on all four ends.

When the slab was loaded to 1 cwt. to the foot super there was no deflection.

At 1¼ cwt. to the foot super there was ⅛ in. deflection in the centre.

At 2 cwt. to the foot super there was ½ in. deflection.

At 2½ cwt. to the foot super ¾ in. deflection.

At 3 cwt. per foot super the test was adjourned for the day with a deflection of $\frac{5}{16}$ in.

On May 24 the test was resumed, when the deflection was found to be 1¼ in.

At a load of 3½ cwt. a slight crack was observed on the under side of the slab, radiating from one corner towards the centre.

At 4 cwt. to the foot super there was a deflection of 1¾ in.

At 4¾ cwt. the slab showed a crack across the centre in the direction of the longest span.

The slab was ultimately loaded to 5¼ cwt. to the foot super, and bore this load for 1½ hours when it collapsed, the fractures occurring at each of the four corners.

The co-efficients of expansion of the two constituents, iron or steel and concrete, are considered for all practical purposes to be identical. The expansion of steel at 500 deg. Fahr. is an inch in 28 ft., and at 1,000 deg. an inch in 14 ft.; when dull red-hot, iron is 1,300 deg. Fahr.

Cement adheres more firmly to iron and steel when left with its natural surface, and not treated by any anti-rust process. When surrounded with good concrete, while free from air, there is little fear that it will gradually corrode.

In some investigations made by the Engineer of the St. Louis Merchants' Bridge Terminal Railway, on the strength and adhesion of 2-in. diameter iron anchor bolts, set 11½ in. in masonry, with lead sulphur and cement, it was found that a rod provided with a screw thread to improve the grip of the cement, began to yield under a test load of 32,000 lbs., and broke at a load of about 50,000 lbs., without developing the strength of the cement joint; while in the case of a rod left plain and smooth, the cement began to yield at a load of 34,000 lbs., but did not entirely part when the rock broke at a load of 67,000 lbs. *The Engineering and Building Record* of 1891, in reporting these experiments, states that the larger blocks of stone could not be accommodated in the machine, but it was inferred that, in a suitable setting, the cement joint on a smooth rod might be made to break the rod. Professor Bauschinjer, of Munich, found that the adhesion of concrete to iron was about 569 lbs. to 668 lbs. per square inch, which, it will be noticed, is greater than the unit assumed for the concrete in this paper, and therefore the latter may, under favourable circumstances, be increased above an assumption of 400 lbs. per square inch. The use of twisted rods certainly offers a better grip than flat bars or wires. The finer a cement is ground, the greater is its adhesive strength. In practice it will be found that the adhesion varies, not only with the quality as well as the quantity of the cement, but also with the quality as well as the quantity of the sand, the porosity of the substances joined together, their degree of saturation, and, of course, the length of time during which they have been joined. While the sand-carrying capacity of a cement bears a proportion to its adhesive capability, yet beyond the proportion of 2 to 1, sand detracts from the resistance more and more rapidly.

The spans may be considerably extended by the aid of the channel arch. The only objection is the exposure of the under surface of the channel metal rib, but this can be kept well painted for preservation: and as regards security, the concrete will be, in time, able to do without it in the same way as cylinders filled with concrete for piers simply form a casing for the pier, the interior concrete itself forming the supporting column of the pier. The surface so exposed is very small compared with the various systems of trough flooring that have been patented.

Channel irons, 6 in. by 2 in. (12 lbs.), 5 ft. centres, have been successfully used in 16 ft. span arches, and 4 ft. centres for 20 ft. 6 in. spans, with Portland cement 4½ in. clinker concrete, 4 to 1, and No. 10 expanded metal. After placing the centering in position and filling the haunches, the expanded metal is laid down horizontally, the sheets being placed lengthwise across the beam and overlapped at the sides and ends. The concrete is then finished off to the required level, while the under concrete is still green, so that the whole arch forms one homogeneous section, leaving a level top with a smooth under surface when the centering is taken away. It may be remarked that the presence of the transverse channel metal arch, firmly held between the longitudinal joists, enables the centering to be removed at an earlier stage than otherwise; but it is prudent not to strike the centering for at least ten days.

Mr. A. Baker, of the Beckton Gasworks, conducted an experiment with a concrete and expanded metal structure, under the instructions of Mr. G. C. Trewby, M.Inst.C.E., consulting engineer to the Gas Light and Coke Company, in which the concrete consisted of ordinary Thames ballast, passed through a ¾ in. sieve, and the Portland cement (of 112 lbs. per bushel, 10 per cent. residue on 2,500 mesh sieve, 450 lbs. tensile strength, after twenty-eight days' immersion), in the proportion of one of cement to four of ballast. The expanded metal was introduced in sheets 17 ft. by 5 ft. 6 in. wide, 3 in. mesh, ¼ in. by $\frac{3}{16}$ in. strands. The structure consisted of a 6 in. slab of concrete, 17 ft. clear span by 10 ft. wide, supported for purpose of experiment upon three jack arches spaced at 4 ft. 9 in. centres. These arches were formed of curved channel irons, 6 in. by 2½ in. section (at 12½ lbs. per foot), with a rise of 2 ft. in the 17 ft. span, filled up with concrete 6 in. above the soffit, thus making a level bearing, on which the slab rested.

The abutments were built with steel joists secured by five wrought iron straps 4 in. by 1 in., the foundation being formed of ordinary railway sleepers laid crosswise on the firmest ground that could be found upon the site. After setting thirty-four days the trial weight in the form of rails (56 lbs. per yard) was gradually applied. These rails were laid on top of a course of blue Staffordshire bricks to ensure an evenly distributed load. With a load of 27 tons a slight crack was observed running diagonally through the concrete of No. 1 arch about 6 ft. from the north abutment, and a similar flaw was noticed in No. 3 arch in about the same position when 38 tons had been applied. But as these did not widen out or extend in any way during the remainder of the test, very little importance was attached to them, as they were considered to have been caused by a slight spreading out of the abutments. At this point the average deflection of the three channels was $\frac{3}{16}$ in. A certain number of rails were added each day until 100 tons (equivalent to 11·8 cwt. per superficial foot) was equally distributed over the slab; but this did not seem to have any appreciable effect on the structure, the deflection of the channel irons being 1 in. and of the concrete slab barely $\frac{1}{2}$ in. In places the channel irons parted a little from the concrete, but not more than $\frac{1}{8}$ in. In Mr. Baker's report he states that, after letting this weight remain for three weeks, an additional 26 tons were added, the result being a slightly increased deflection. Soon after commencing to load the next morning it was seen that one corner of the foundation was sinking, throwing the weight over on that side. No. 3 channel iron showed signs of buckling close to the foot, and the concrete in the three arches began to disintegrate by the abutment. The total weight evenly distributed over the structure was 128 tons 5 cwt., equal to 15·09 cwt. per square foot. The slab was carefully examined at this stage and found to be intact, with the deflection in the centre of $\frac{1}{2}$ in. The average deflection of the channel irons was $1\frac{3}{16}$ in., all three keeping their shape very well with the full load on.

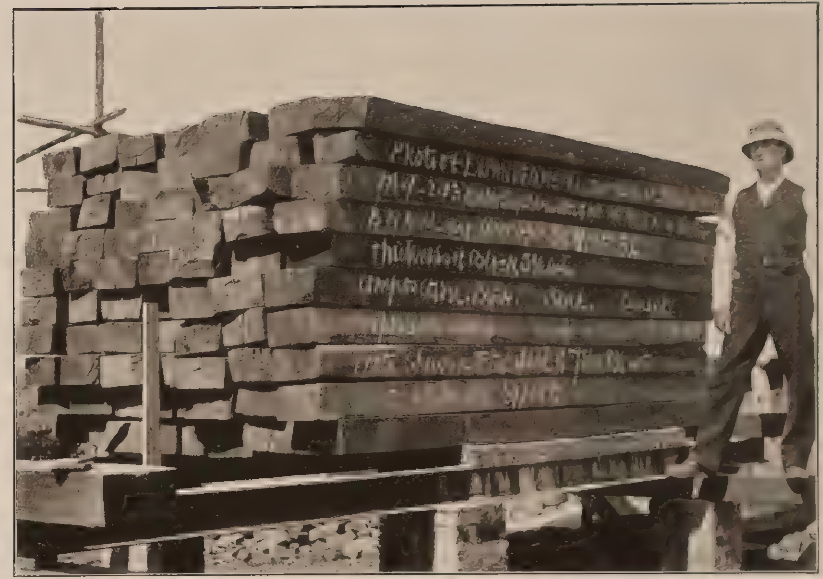
Area of slab	170 square feet.
Structure finished	November 2, 1899.
Commenced loading...............	December 4, 1899.

It may be of interest to hear that expanded metal has been used in many of the new buildings at Beckton with satisfactory results.

The cost of the use of expanded metal depends in no small degree upon the extent of the work. The makers prefer to include the concrete in their contract when they are expected to undertake responsibility for the stability of a structure involving the use of expanded metal. The saving, however, is mainly in weight and head room, although, as hinted in this paper, there may be cases where a tubular top might be advantageously introduced, whereby strength would be attained without increased weight, though at the expense of reduction in headway.

The fact that the introduction of metal into concrete as a tensile element is advantageous is generally accepted, and the author trusts that his paper may elicit a discussion upon the subject suggestive of desirable improvements (if any) in the size of the meshes which are formed in the metal or of further experiments needed in the application of expanded metal to concrete structures. Hitherto it has been chiefly used in cases where the steel work for floor construction has been already designed. The best and most economical results would be obtained by a disposition of framework calculated to suit the carrying-power of the concrete with the aid of expanded metal, whereby the user could employ concrete of a wider span than when employing plain concrete.—*Extract from "The Builder," September 15th*, 1900.

Test at Bombay, India.



Test at Khragpur, India.

Directions.

THE dimension across the short way of the diamond is used to distinguish the various meshes of Expanded Metal that are manufactured, and thus the various meshes are known as $\frac{1}{4}$ in., $\frac{3}{8}$ in., $\frac{3}{4}$ in., $1\frac{1}{2}$ in., 3 in. and 6 in. respectively.

Each mesh is manufactured in a number of weights, and from plates varying in thickness, and thus over 60 different weights are produced.

The Metal is supplied in sheets of suitable size for the work in hand, and can be cut up to 16 ft. long, the long way of the meshes, by any convenient sizes, the short way of the meshes.

The usual type of Expanded Steel used in Armoured Concrete Construction is that known as 3 in. mesh. This mesh measures 3 in. by 8 in. from centre to centre of intersections, and, obviously, each intersection is twice the sectional area of its strand. As the Metal is stronger when the sheets are laid with the long way of the meshes from support to support, it should be used in that manner.

The Expanded Steel introduced into concrete as tension member should be calculated to resist the loads the structure is designed to carry, as the concrete is used as compression member only, and the necessary factor of safety must be allowed for. The reports of tests upon the material show the ultimate strength that may safely be reckoned upon, and attention is called to the quality discovered by these tests, viz., that the strength of the material is greatly increased by the process of distention.

As stated above, the concrete is used as compression member only, no account being taken of any tensional quality it may possess, and its strength in this capacity should be calculated to equal the tensional strength of the Steel.

The cohesion between steel and concrete has been proved to be thoroughly satisfactory, and it is an accepted fact that steel is preserved by cement concrete. Further, for all practical purposes, the expansion and contraction of the two materials under varying temperatures, may be taken to be exactly similar.

The area of steel in section as compared with the sectional area of the concrete should be as 1 : 200 or $\frac{1}{2}$ %. Thus No. 9, 3 in. mesh, $\frac{3}{16}$ by $\frac{1}{8}$ strand, is the correct weight for 3 in. concrete; No. 8, 3 in. mesh, $\frac{1}{4}$ by $\frac{1}{8}$ strand, for 4 in. concrete, and so forth to No. 30, 3 in. mesh, $\frac{3}{8}$ by $\frac{3}{16}$ strand, for 9 in. concrete. If a greater strength is required than that obtained by one layer of Expanded Steel with its necessary thickness of concrete, two or more layers can be introduced, and the concrete thickened accordingly. The above figures are proved as follows: There are eight strands in section in one foot run of 3 in. mesh, therefore, taking No. 8 metal and 4 in. concrete:

$$8\left(\tfrac{1}{4}\times\tfrac{1}{8}\right)=\tfrac{1}{4}$$
$$12\times 4=48$$
$$\tfrac{1}{4} : 48 :: 1 : 192$$

which is practically one-half per cent.

After the temporary centering has been erected, the Expanded Steel should be laid immediately upon it, with not less than one mesh lap in each direction where the sheets join. The long way of the mesh should run from support to support, and the sheets should lap on supports wherever possible.

The metal should not be painted when used in conjunction with concrete.

If the concrete is to be thin, say 3 ins., and it is found that the Expanded Steel bulges slightly when laid in position, a few nails may

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NOTE.—Generally speaking, the 3'' meshes specified and quoted for in the published price list of the Company, are found to be sufficient for ordinary requirements. In cases, however, where a special weight of Expanded Steel is required, application should be made to the Company for information and prices, as the machines are capable of cutting heaver weights than those set forth in the list. For instance, some 3 in. mesh with strands $\frac{1}{2}\times\frac{3}{16}$ in section have lately been cut for a large water conduit.

be driven into the centering to hold the metal down. These nails will remain in the concrete when the centering is struck, but can be broken or clipped off in the ordinary way.

The Expanded Steel being in position, the concrete should be placed upon it and thoroughly well scraped, spaded and tamped down and into the meshes to ensure the metal being completely embedded, and the meshes entirely filled.

If the concrete is to be faced, say with sand and cement, or granolithic finish, the facing should be applied while the concrete is green, but if this cannot be done, and the facing has to be applied after the concrete has gone off, the latter should be well swept and freed from dust, wetted with clean water, and, if necessary, sprinkled with dry cement to ensure the facing taking properly to the concrete.

The concrete should be turned three times dry, and three times after water has been added, and should be composed of 4 parts of approved aggregate, say clinker, brick, slag, stone granite, etc., broken to pass a $\frac{3}{4}$ in. mesh sieve, and having about 30% of fine stuff in its measure, to one part of best Portland Cement. Of course, these proportions may be varied to meet various requirements.

The temporary centering should be allowed to remain in position for from 10 to 15 days according to the class of work, weather, etc., and should be lime-whited, washed with soap water, or covered with oiled paper, to prevent the concrete adhering to it; the oiled paper gives the best results and can be easily stripped off after the centering has been struck.

If the foregoing method with regard to the laying of the concrete is adhered to, the action of scraping and tamping it down will lift the Expanded Steel into its ideal position, viz.: about $\frac{1}{2}$ in. from the face of the concrete.

Foundations.

THERE is no concrete work in which Expanded Steel can be more advantageously employed than in foundation work.

To begin with, the great advantage of Expanded Steel and concrete foundations is that they are much cheaper than concrete foundations without Expanded Steel, as the introduction of the metal as tension bond eliminates about 75 per cent. in bulk of the concrete.

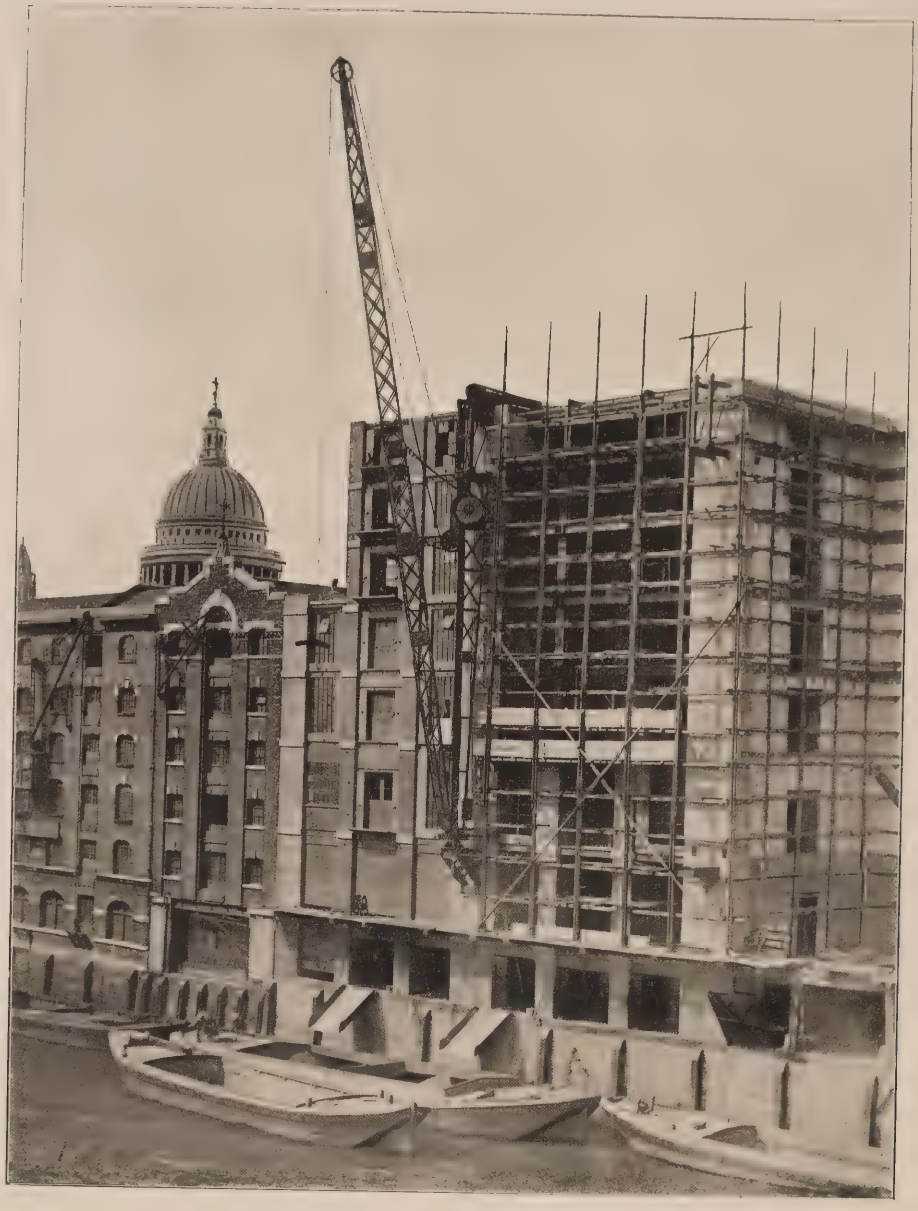
The metal cannot oxidise, because it is hermetically sealed in the concrete, and, owing to its open mesh formation, it cannot slip within the concrete. Foundations of Expanded Steel and concrete have occasionally been removed after having been many years in place, and in not a single instance has the metal been found in a rusty or impoverished condition. On the contrary, it has invariably been found to be in exactly the condition it was in when first placed in the concrete.

It may be that a large area of land will not subside equally all over, but it will subside or settle in places. Now, concrete, with an Expanded Steel tension member, will bridge over any such local settlement, whereas concrete alone will undoubtedly crack and settle with the land. This has been experienced over and over again.

Many large buildings stand upon a raft of Expanded Steel and concrete, and there is not a shadow of a doubt that Expanded Steel is better adapted for the purpose than, say, old railway metals, rolled steel joists, rods, pipes, etc., as the latter split the concrete up into blocks and destroy the homogeneity of the slab, whereas the former, on account of its peculiar formation, becomes thoroughly incorporated with the concrete, and thus forms one solid mass.

To give an example, where the ordinary concrete footing would be about three feet in thickness, a nine inch footing with a tension bond of No. 30 Expanded Steel near its underside will give the same results at a much lower cost.

FLOORING, CEILINGS AND PARTITIONS, AND FLAT ASPHALTED ROOFING.



KENNET, WORCESTER AND VINTRY WHARVES.

COLD AIR STORES,
Upper Thames Street, London, E.C.

Mr. HERBERT COWARD, Engineer.

The Channel Arch-Floor.

THIS patented system has been widely and successfully adopted in many important buildings with spans of from 12 ft. to 25 ft. between mains, and the arches 4 ft. to 8 ft. apart, according to load required, formed of curved steel channels 6 in. in width, weighing about 12 lb. per foot run, but the weights and sections may be varied according to requirements. Upon these the concrete is built up to the floor level. As a strong and economical construction of floors for warehouses, mills, factories, &c., it cannot be excelled.

After placing the centering in position and filling the haunches, the Expanded Steel is laid down, the sheets of convenient sizes being placed length-wise across the beams or arches, and overlapped at the sides and ends. The concrete is then spread over the surface and thoroughly tamped down. This process results in the metal becoming embedded in the lower part of the slab, thereby leaving a smooth underneath surface when the centering is removed.

Details of practice with our different systems will vary somewhat, according to varying requirements, as will be apparent from the illustrations. The economy, as well as questions of desired strength and weight, must be separately considered and calculated for each case presented.

The full value of our systems of construction, from an economic standpoint, is not accomplished without the use of specially selected and arranged steel or ironwork in accordance with the particular needs. The weight of our floors is so much less than heavy tile or other bulky methods of construction that a great economy is possible in the iron-work and even the foundation of the structure. The concrete slabs constituting the actual floor need not exceed an average weight of from 25 to 30 lbs. per square foot. It is submitted that architects and engineers should take this fact into their consideration when plans are being prepared or submitted for estimates.

The series of illustrations given clearly explain the method of erection adopted in the construction of our fire-resisting concrete floors when carried upon arched channel ribs. Upon reference to the photographs, but little further explanation will be necessary. The illustrations indicate the forms and arrangements of the steel joists and curved channel arches, the weights and spans of which will vary according to the loads to be carried and other requirements. The arrangements and functions of the temporary centering boards, by which the concrete spandrils and flooring are formed, will be apparent.

The sheets of Expanded Steel are shown as directly and horizontally laid across the top flanges of the girders and the finished level of the concrete haunches; upon these sheets the concrete floor is laid, as shown and before described. Attention is directed to the uniform and continuous nature of the finished structure thus formed.

The illustrations on pages 34–37 represent the actual construction of the channel rib floors as carried out at the Manchester Ship Canal Warehouses.

The amount of rise allowed in the arches should in all cases approximate as nearly as possible to 1 in. per foot of span.

When straight auxiliary joists have to be notched, "joggled" and carried by brackets, secured to the webs of main girders, the cost is usually much greater than that involved by the introduction of the cut and curved channel irons, which simply rest on the bottom flanges of the girders and only weigh about 12 lbs. per ft.

If spans of, say, 16 to 25 ft. were bridged by the use of ordinary straight joists the weight of metal per ft. run required would be at least 30 lbs., or more according to the load required; therefore, the saving effected by the use of the channel arch system is often pronounced, and the more so in floors destined to carry very heavy loads.

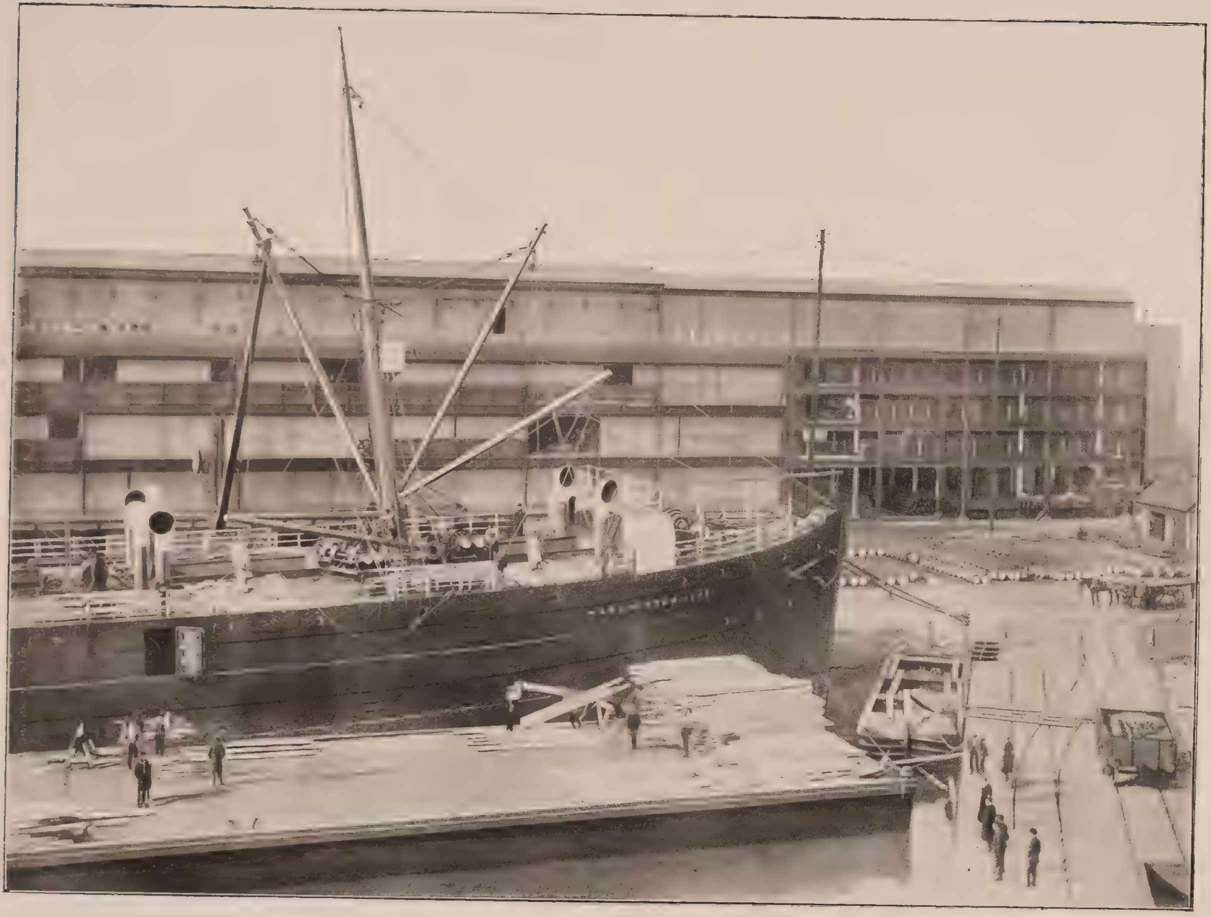
In practice, floors of this description may be effectually constructed so as to withstand any live loads up to 20 cwt. per super foot. The average dead weight of such a structure, with its supporting ribs, need not exceed 30 lbs. to 40 per sq. foot of floor area, while the cost is less than that of other systems.

An ultimate strength of about a ton to the square foot is manifestly in excess of most practical requirements; indeed, after allowing a factor of safety of four, the ultimate resistance required for a factory floor seldom exceeds 16 cwt. per super foot.

When the load to be carried is not abnormally great, the span of the channel ribs can be safely extended to fully 25 feet. By increasing the depth or sections of the channels, it will be apparent that very heavy loads may be sustained or unusually large spans securely effected.

FLOORING.

Cambered Steel Channel and Concrete Ribbed Patented System.



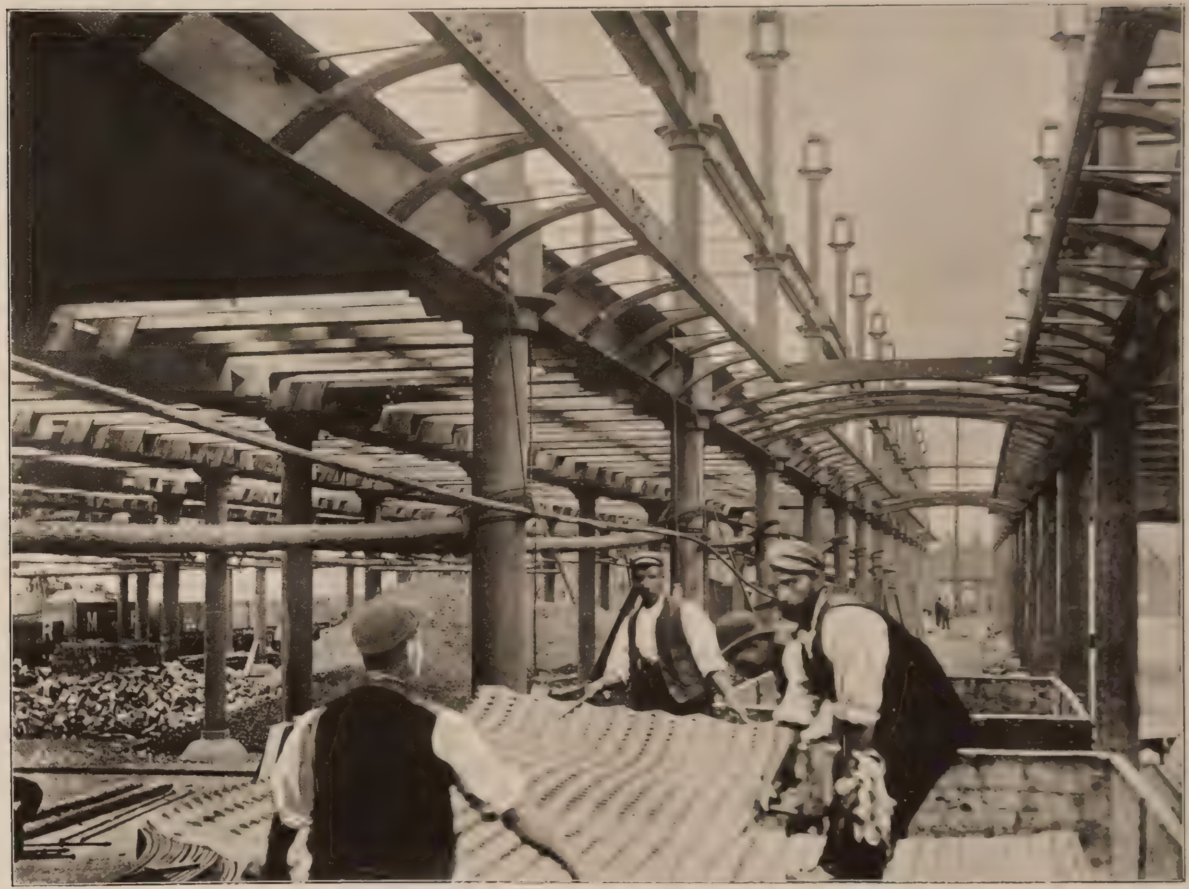
The Manchester Ship Canal Warehousing Company, Ltd.

WAREHOUSES.

Mr. W. HENRY HUNTER, Engineer.

FLOORING.

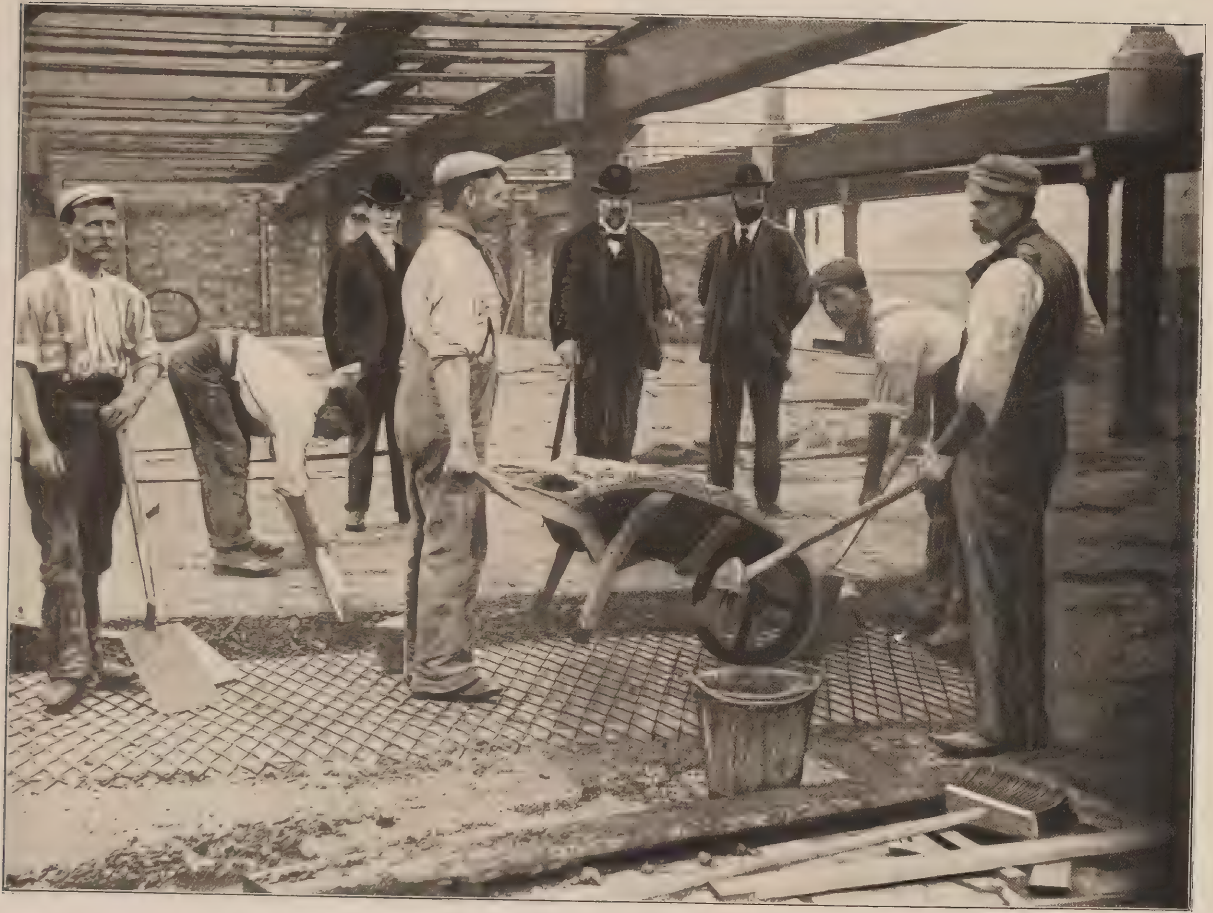
Cambered Steel Channel and Concrete Ribbed Patented System.



The Manchester Ship Canal Warehousing Company, Ltd.
WAREHOUSES.
Mr. W. HENRY HUNTER, Engineer.
Shewing Flooring in course of Construction.

FLOORING.

Cambered Steel Channel and Concrete Ribbed Patented System.



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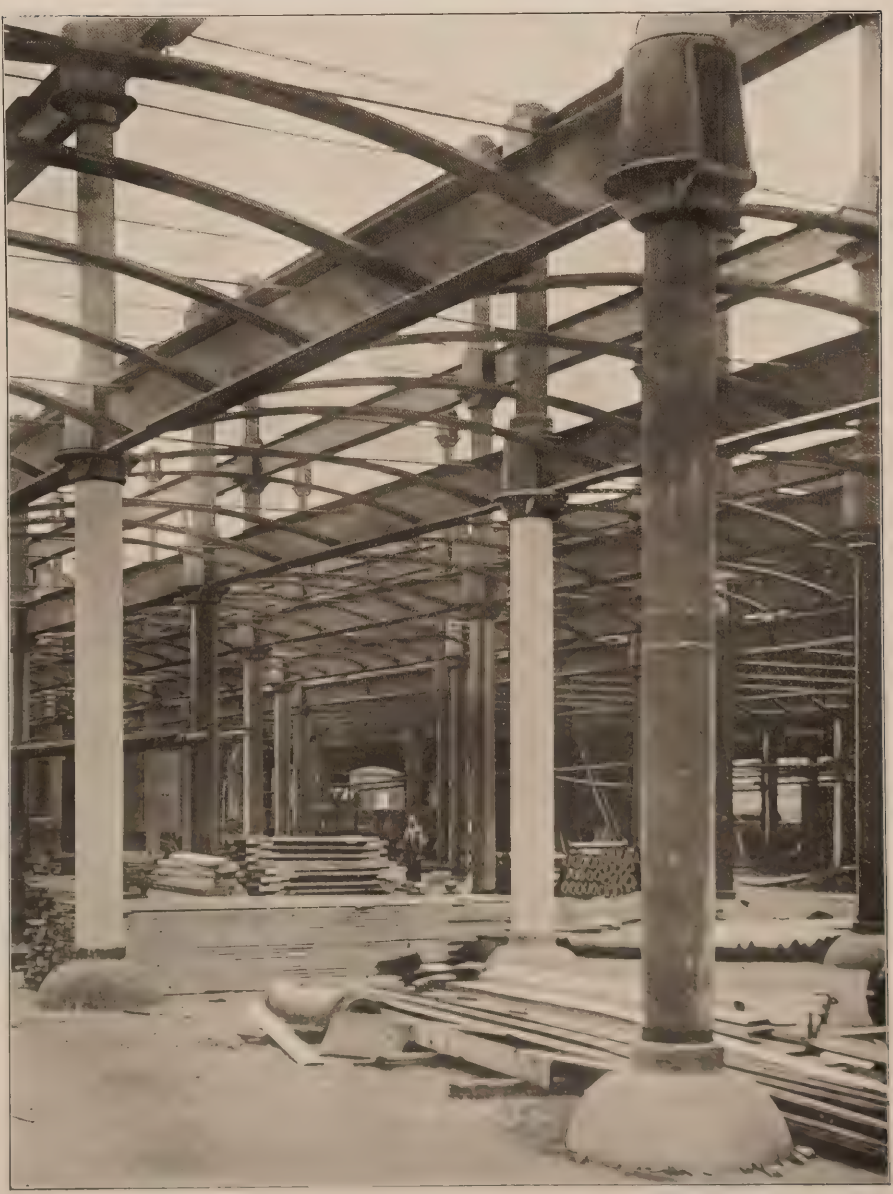


Manchester Ship Canal Warehousing Company, Limited.

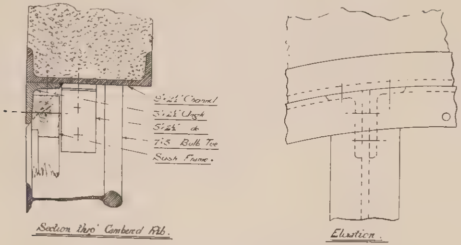
WAREHOUSES.

Mr. W. HENRY HUNTER, Engineer.

New Stores at Elswick Works.

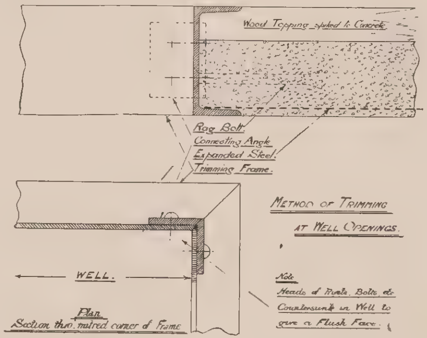
THE Blast Furnace Site Stores at Elswick Works are a fine example of Steel framed building construction, and were designed by Mr. Frank W. Rich, Architect, of Newcastle-on-Tyne. The main structure was carried out by Messrs. De Bergue of Manchester, and our cambered channel floors are used throughout. The building is two storeys in height, the upper floors forming galleries around the centre portion, which has a ground floor only, open to the glazed roof, with electric travellers running the whole length of the building for the purpose of handling the materials which are kept in the stores. The upper floors and roof are carried on built up steel stanchions at about 20 feet 6 inch centres. The galleries are about 36 feet in width, run the whole length of the building, and are carried on main girders connected up to the stanchions. Thus, the cambered channel and concrete secondary ribs are of 20 feet 6 in. span, and, in the case of the first gallery flooring, 5 feet, centre to centre, and in the case of the second gallery flooring 6 feet, centre to centre, to carry 5 and $2\frac{1}{2}$ cwts. per foot super respectively; the first gallery flooring being 5 inches in thickness with a tension bond of No. 10, 3 inch mesh, $\frac{1}{4}$ inch by $\frac{3}{16}$ strand Expanded Steel, and the second 4 inches in thickness, with a tension bond of No. 8, 3 inch mesh, $\frac{1}{4}$ inch by $\frac{1}{8}$ inch strand Expanded Steel.

A cambered rib is used as trimming to the floors, and on the outside of the building cambered angle iron is riveted to the web of the channel and holed at every twelve inches, so that segment headed sashes bolted to it are perfectly weather tight—detail thus:—



METHOD OF FIXING WINDOW SASHES

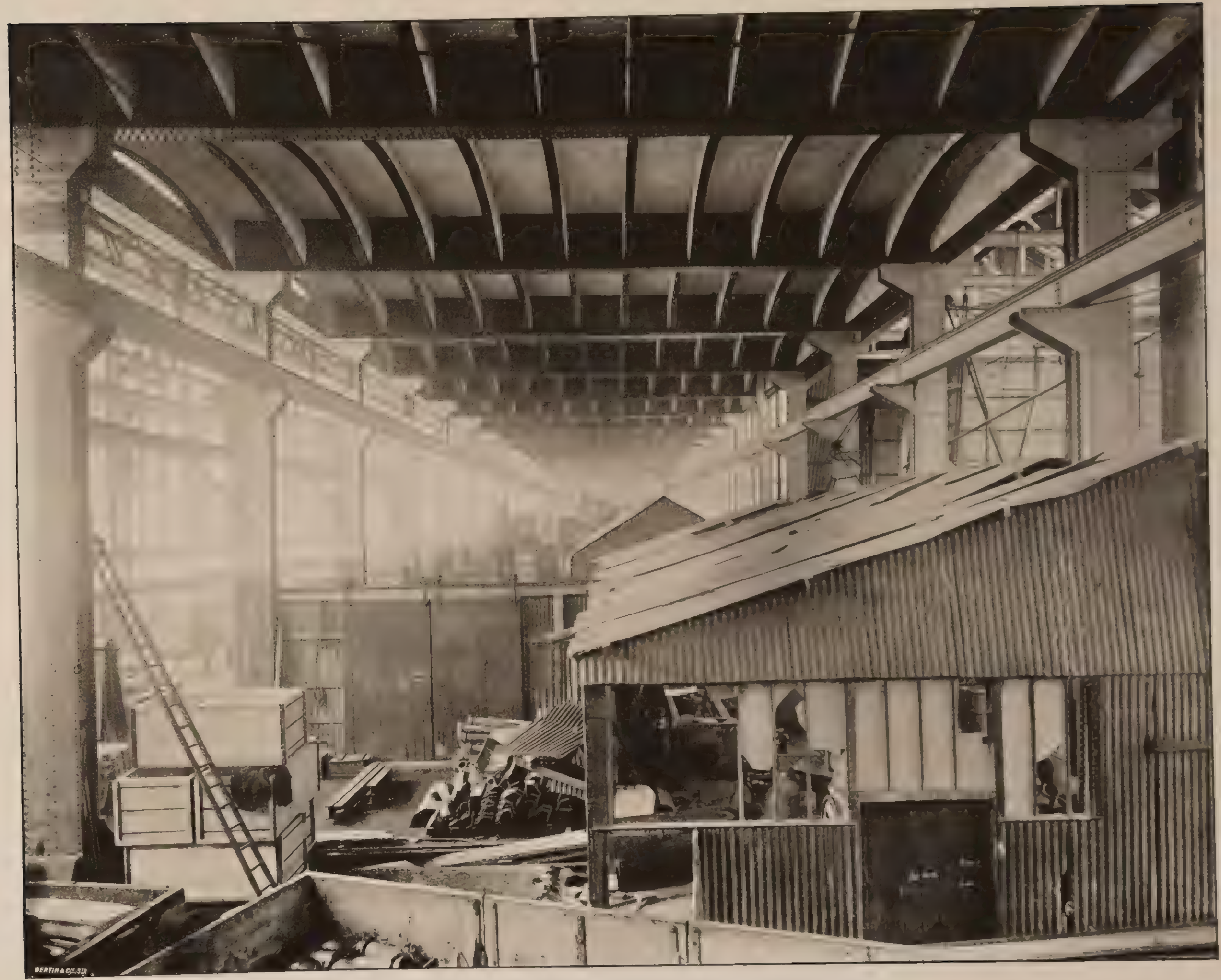
These sashes meet a dwarf wall carried on the floor and give a pleasing effect when finished. Wells for stairs, lifts, etc., are trimmed with channel frames properly mitred at angles and secured to the concrete with rag bolts—detail thus:—



METHOD OF TRIMMING AT WELL OPENINGS.

The roof is likewise of steel framed work carrying glass and slates, and the whole construction is so easy and expeditious that it could be adopted with like success in many instances, as it has many obvious advantages over the well worn brick construction.

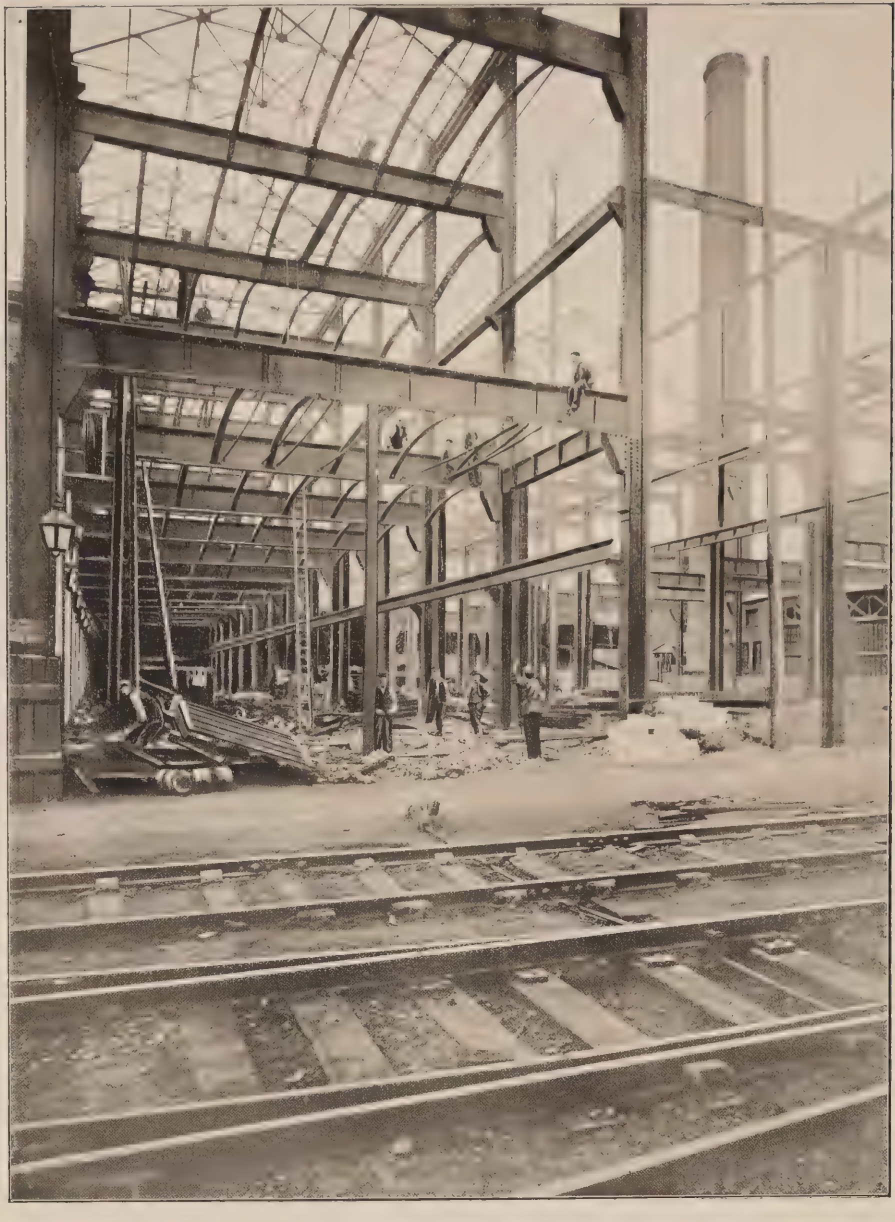
FLOORING.—Cambered Steel Channel and Concrete Ribbed Patented System.



Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd.—Elswick Works. Shops.
Mr. FRANK W. RICH, F.R.I.B.A., Architect.
Showing Flooring finished on underside.

FLOORING.

Cambered Steel Channel and Concrete Ribbed Patented System.



Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd.
ELSWICK WORKS.
Stores: Blast Furnace Site.
Mr. FRANK W. RICH, F.R.I.B.A., Architect.
Showing Steel Framework in course of construction.

Extract from "JOURNAL OF GAS LIGHTING, WATER SUPPLY, &c.," January 13th, 1903.

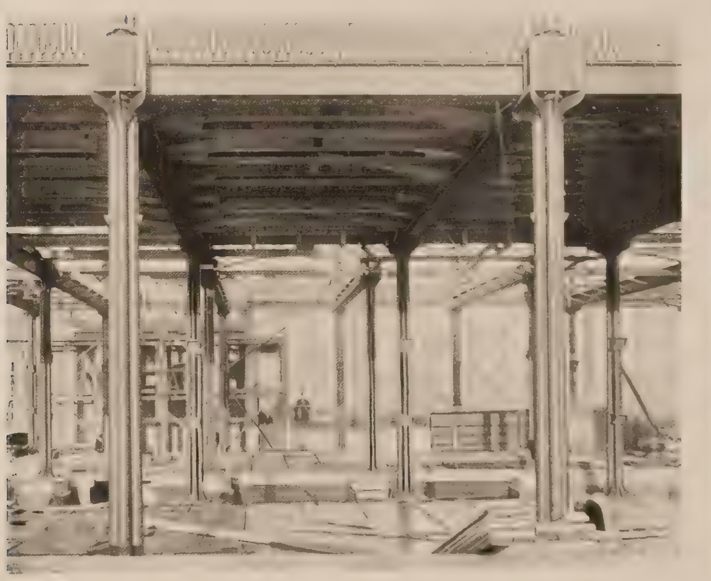
THE EDINBURGH & LEITH CORPORATIONS GAS COMMISSIONERS.

GRANTON GAS WORKS.

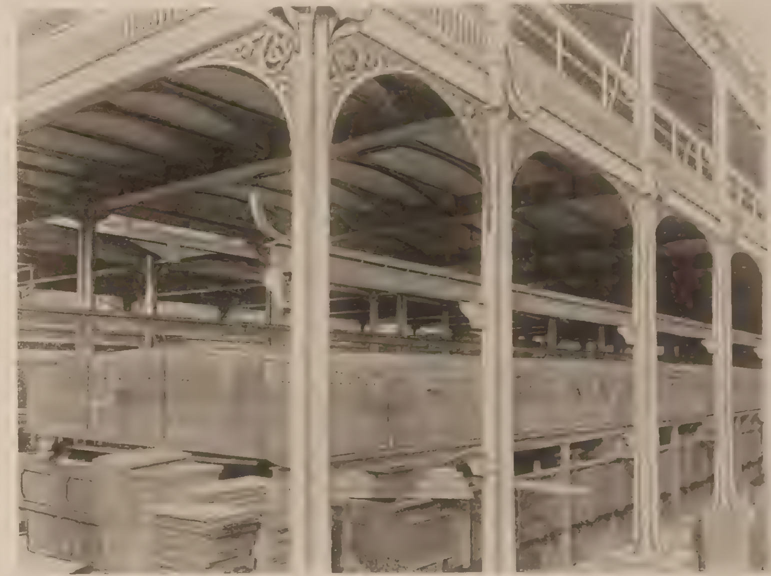
Mr. W. R. HERRING, M.I.C.E., Engineer.

THE story of the inception of the Granton Gas Works and the facts and circumstances which induced the Commissioners to launch such a bold scheme of gasworks combination have been told in a series of articles by the engineer, Mr. W. R. Herring, M.I.C.E., which have already appeared in the columns of the *Journal of Gas Lighting, Water Supply, &c.*, and, while it may on some future occasion be written in more deliberate sequence, for the present it is sufficient for our purpose to give a few illustrations and extracts from the above-named journal with regard to the adoption of our material.

Wherever necessary the concrete foundations were reinforced with a tension bond of Expanded Steel, and the whole of the



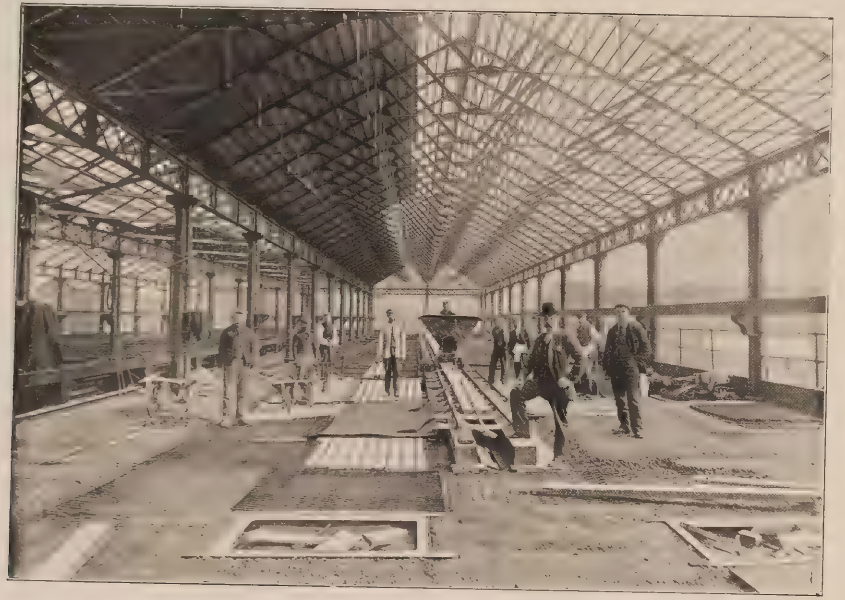
Shewing Cambered Channels and Centering in position ready to receive Concrete Ribs and Expanded Steel.



Shewing Flooring finished on underside.

suspended flooring is on our systems. Many thousands of square yards of Expanded Steel were used in the course of construction of these works, and the details given below fully explain the methods and uses of its application :—

"A careful calculation was made as to the probable weight that would require to be supported by the retort-bench foundations. The division walls, as already stated, were 12 feet centre to centre and 2 ft. 9 in. in width ; leaving an intervening space of 21 ft. 2 in. by 9 ft. 3 in., which was filled in with surplus earth. Resting upon these walls, a bed of concrete extending slightly more than the full length of the bench, and in breadth 21 ft. 2 in. (the neat brickwork of the bench being 17 ft. 2 in. in breadth) was to be laid ; and it was found that, by inserting expanded metal mesh, 18 inches of concrete would be ample to carry the superincumbent weight of the retort settings.



Shewing Expanded Steel and Trimming Frames in position ready to receive Concrete.

"Expanded metal is now comparatively well known among engineers, but it may not be out of place to add a few explanatory details. It is formed by expanding 'solid flat sheets or plates of various thicknesses and metals into lattice or mesh-work.' Its cost is comparatively small, when its advantages are taken account of, as well as its simplicity and absolute reliability—affording as it does that transverse and diagonal bond to concrete works under tensile stress, that is a very important factor in engineering structures. In brief, expanded metal consists of sheets of metal mechanically slit or cut, and deployed or opened out, in such a manner as to produce trellis or net-like work of diamond-shaped meshes, with strands of varying sizes and thicknesses

It will be understood that this process produces a fabric of from two to twelve times the covering area of that of the original sheet, according to the size of the diamond-shaped meshes and depths of strands. A sheet of the expanded metal may be cut to any size required without reducing its aggregate strength materially for a given area. From numerous experiments, it has been ascertained that the insertion of this thin sheet of open-work metal in a slab of concrete, increases the carrying power of the concrete fully tenfold. The sheets can be procured up to 16 feet long by

8 feet wide, and for greater length the sheets are over-lapped on the mesh and clipped together. This was done in the instance under review; the metal being laid from pier to pier the long way of the mesh. The expanded metal used was made of very mild steel, having an ultimate resistance of about 22 tons per square inch, with 21 per cent. elongation in 8 inches. The sheets were of No 10A pattern, having meshes 3 inches wide and 8 inches long; and the substance of the strands gauging $\frac{3}{8}$ inch by $\frac{3}{10}$ inch. It was estimated that the 12 inches of concrete with the metal embedded in it could carry a safe load of 8 cwt. per foot super, at the clear span between the walls; the space being filled in with earth and rammed solid. The sheets were laid down immediately upon the filled-up ground with the ends resting upon the division walls on either side, and carefully overlapped and bonded on the sides. The concrete mixture was then brought forward in the tipping-waggons on the light railway and emptied out, spread over the surface and thoroughly tamped down—the metal being eased up with shovels to ensure the concrete getting underneath and all round about and through it. This process results in the metal becoming embedded in the lower part of the slab, thereby obtaining its greatest efficiency for the purpose under review, and the whole constituting an efficient binder. The concrete was laid in two layers, each 9 inches thick; the proportions being seven parts of broken stone or brick to one part of Portland cement—the whole being broken and mixed through the stone crusher and concrete mixing machine.

Shewing Flooring finished on topside.

"The foundations for the benches, as already explained, consist of a slab of expanded metal enforced concrete resting upon the transverse supporting walls carried down to the solid Figs. 1, 2, and 3 show the formation of these foundations; the brick encased concrete piers 21 ft. 2 in. long by 2 ft. 9 in. wide, descending to the solid ground. The foundations for the end or buttress walls are broader for the thicker end walls of the bench, as well as being extended to form the chimney bases. Fig. 1 shows the expanded metal in position, prior to placing the bed of concrete thereon; and it more particularly illustrates the pockets which were formed in the concrete for receiving the ends of the front, back, and end buckstays, together with the 4-inch by $\frac{3}{4}$-inch flat-steel bent straps, embedded in the concrete, to act as ties to the feet of the buckstays."

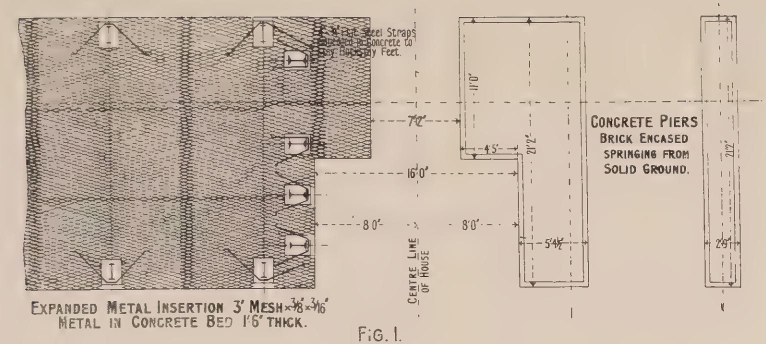
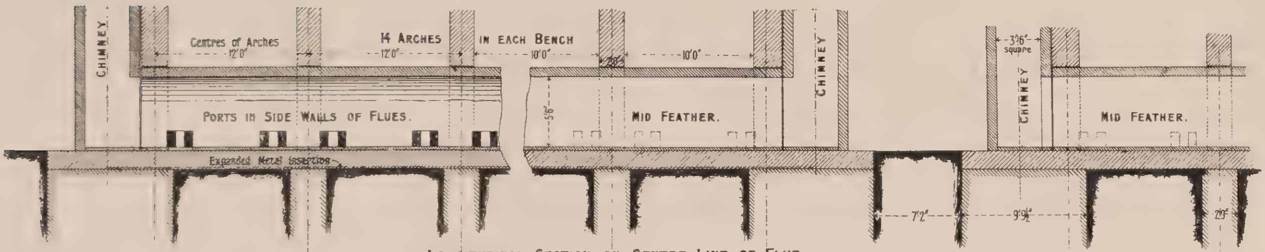
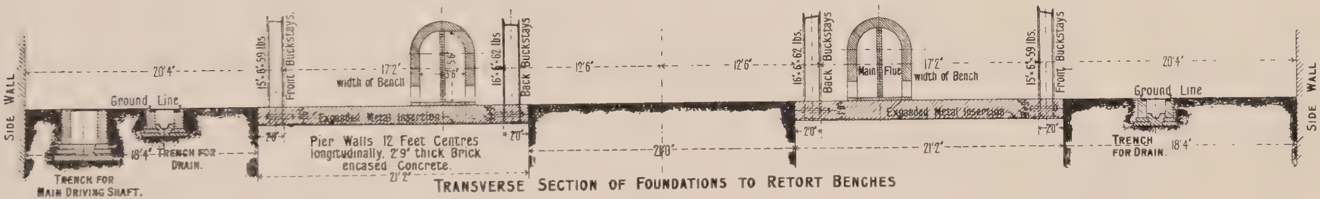

3" × 1" Steel Straps embedded in Concrete to carry Buckstay Feet.
7'2"
11'0"
4'5"
21'2"
16'0"
8'0"
8'0"
5'4½"
CONCRETE PIERS
BRICK ENCASED
SPRINGING FROM
SOLID GROUND.
21'2"
2'9"
CENTRE LINE OF HOUSE
EXPANDED METAL INSERTION 3" MESH × 3/8" × 3/16"
METAL IN CONCRETE BED 1'6" THICK.

FIG. 1.



LONGITUDINAL SECTION ON CENTRE LINE OF FLUE.

FIG. 2.



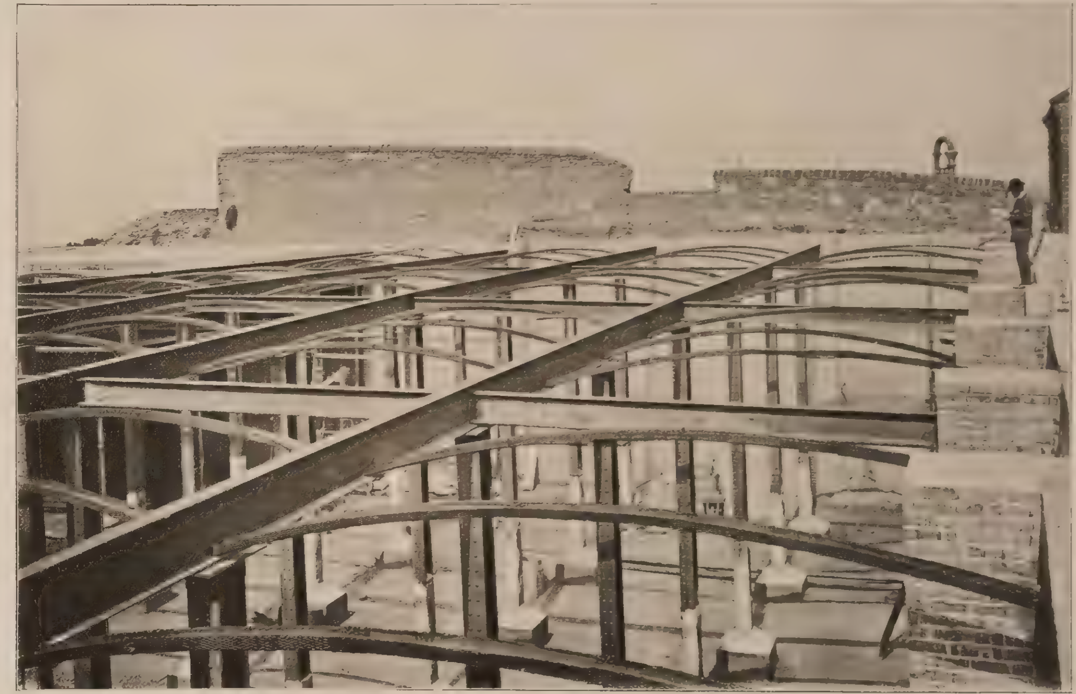
TRANSVERSE SECTION OF FOUNDATIONS TO RETORT BENCHES
LOOKING NORTH.

FIG. 3.

Reservoir, West Kirby, Cheshire.

THE HOYLAKE & WEST KIRBY GAS & WATER COMPANY lately found the demands upon their supply becoming greater than they could conveniently meet; so they instructed their Engineer, Mr. Alfred J. Jenkins, A.M.I.C.E., to draw up the necessary plans, etc., for a further reservoir.

Upon receipt of instructions we submitted a scheme and offer for the cover on our cambered steel channel and concrete ribbed patented system of flooring supported on built-up mild steel stanchions, all steel work to be encased in concrete and Expanded Steel Lathing and cement plaster. The calculations for the cover were worked out on the basis of a safe-working load of 3 cwt. per foot super.



NEW SERVICE RESERVOIR.—No. 1.—Shewing Steelwork.
Mr. ALFRED J. JENKINS, A.M.I.C.E., Engineer.

Mr. Jenkins finally decided to accept our offer, and in due course the work was put in hand.

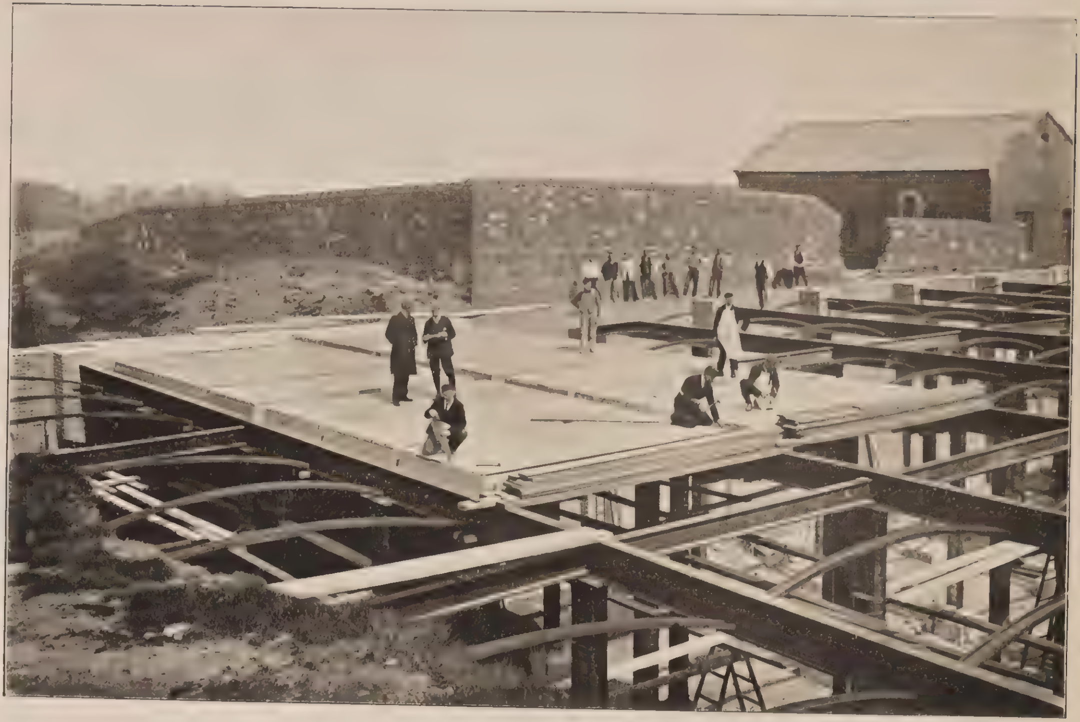
Illustration No. 1 shows the steel work in position and some of it partly encased. It will be noticed that the cover is split up into bays by rolled steel joists, the main joists being about 16 ft. 6 in. centres, and the secondary joists 30 ft. centres connected up to the main joists along alternate lines of stanchions. The mains are securely bolted to the stanchion heads and the secondaries cleated to the mains. Each 30 ft. by 16 ft. 6 in. bay is split up into four smaller bays by our patented ribs at 7 ft. 6 in. centres, and the whole raft of steel work is covered with an Expanded Steel and concrete slab 5 in. in thickness.

To do away with the necessity of plastering the soffit of the cover, oiled paper was laid immediately upon the temporary centering. Upon this paper our Expanded Steel is laid, with the necessary laps, and the concrete, being mixed rather wet, is thoroughly well scraped, trodden and spaded down, with the result that the fine stuff goes to the bottom of the slab and works completely around the Expanded Steel, lifts it about half an inch from the underside, hermetically seals it, thus preventing oxidation of the metal, and gives a soffit at once very hard and smooth.

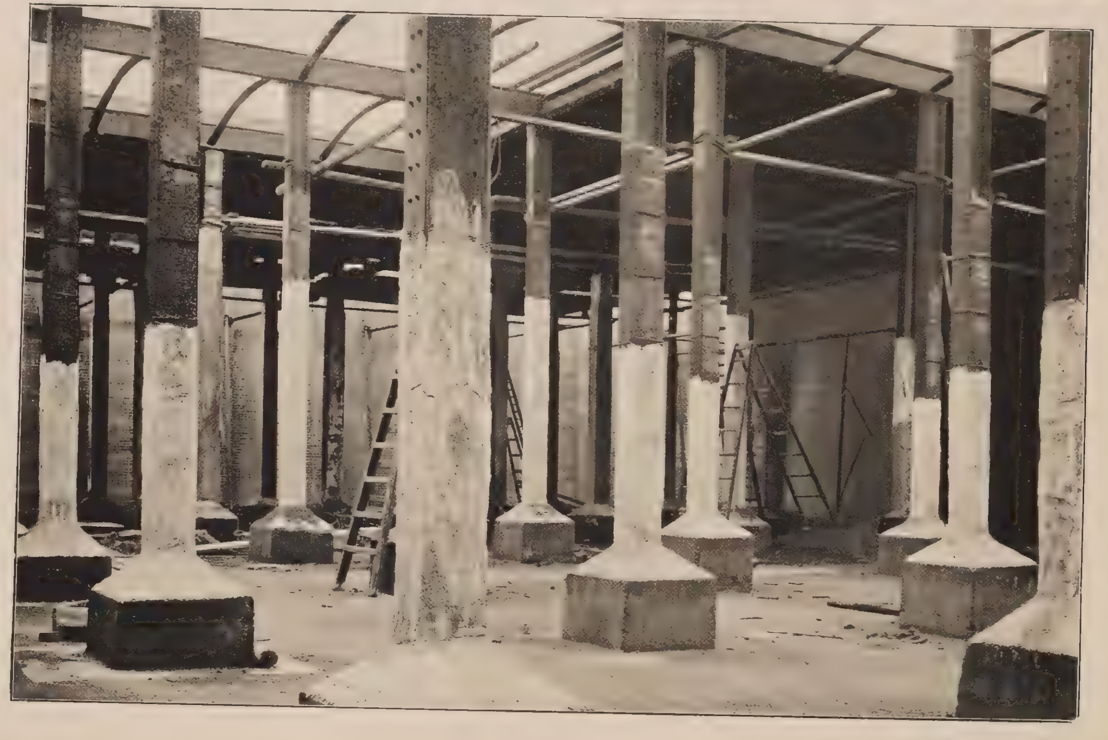
The cover is cambered and falls one foot from the crown at the centre to the surrounding walls. This cambering is obtained by varying the height of the stanchion bases, the length of the stanchions being the same in all cases.

Altogether the job is worthy of frequent reproduction on account of its high efficiency and low cost.

NEW SERVICE RESERVOIR, WEST KIRBY.

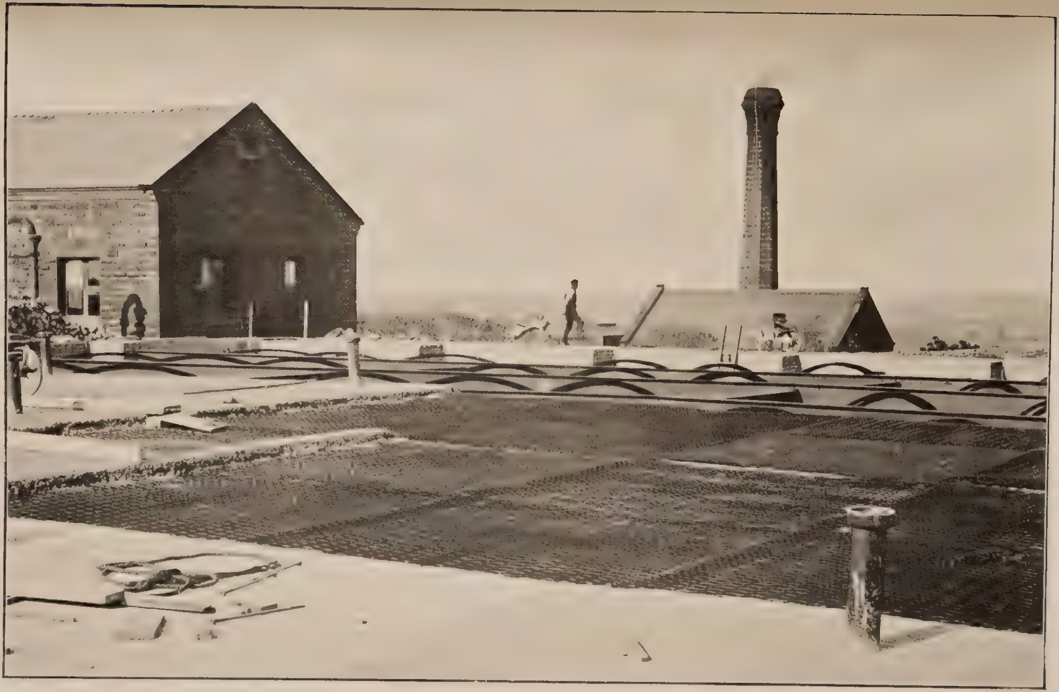


No. 2.—Shewing Temporary Centering.

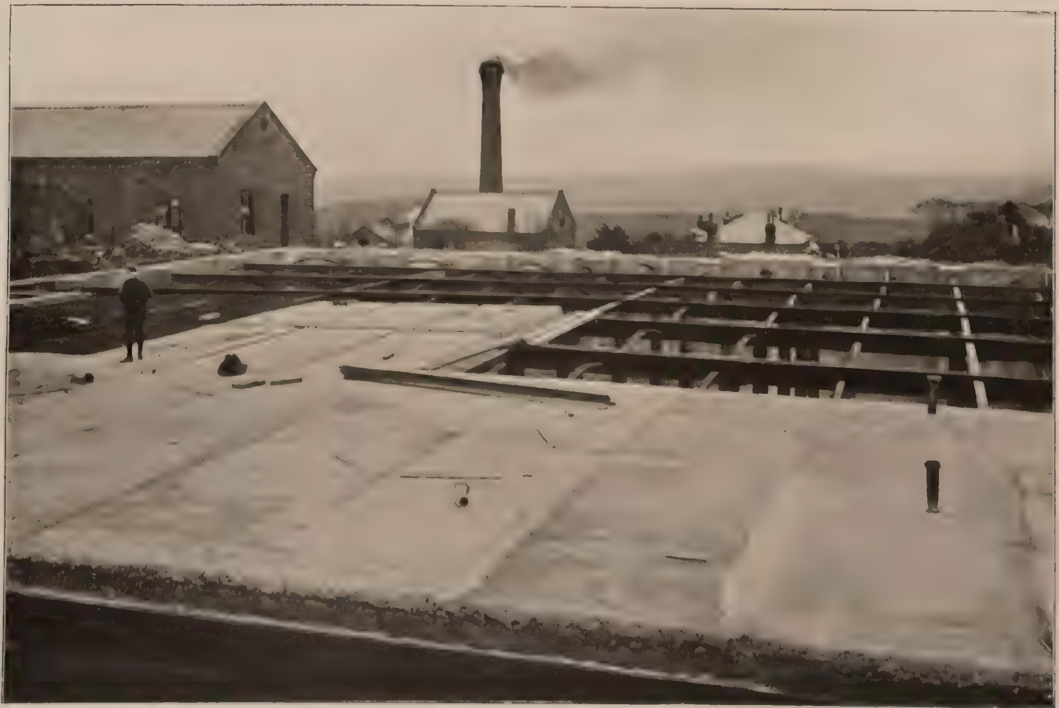


No. 3.—Shewing Steelwork Encasing.

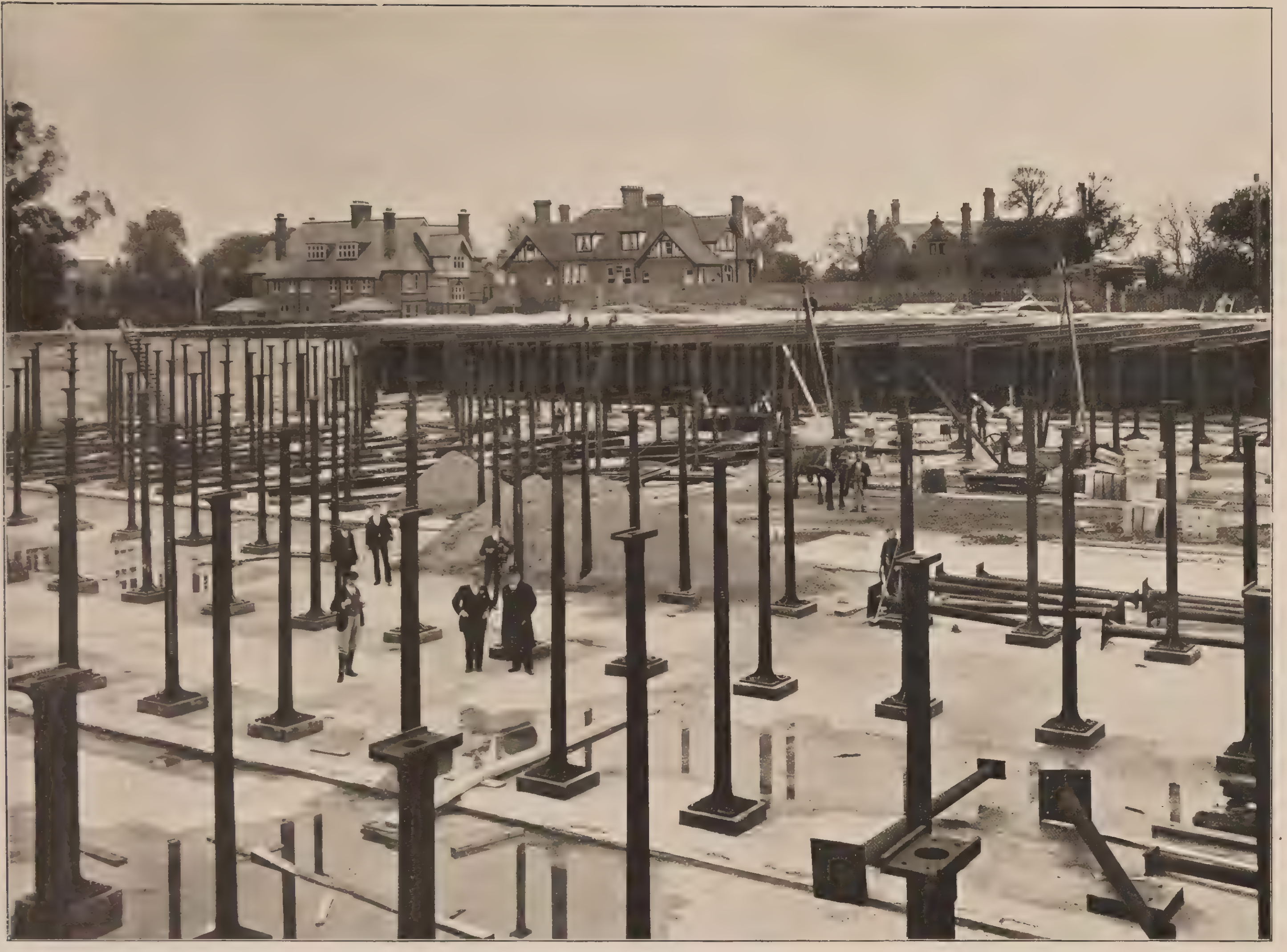
NEW SERVICE RESERVOIR, WEST KIRBY.



No. 4.—Showing Expanded Steel ready to receive Concrete.



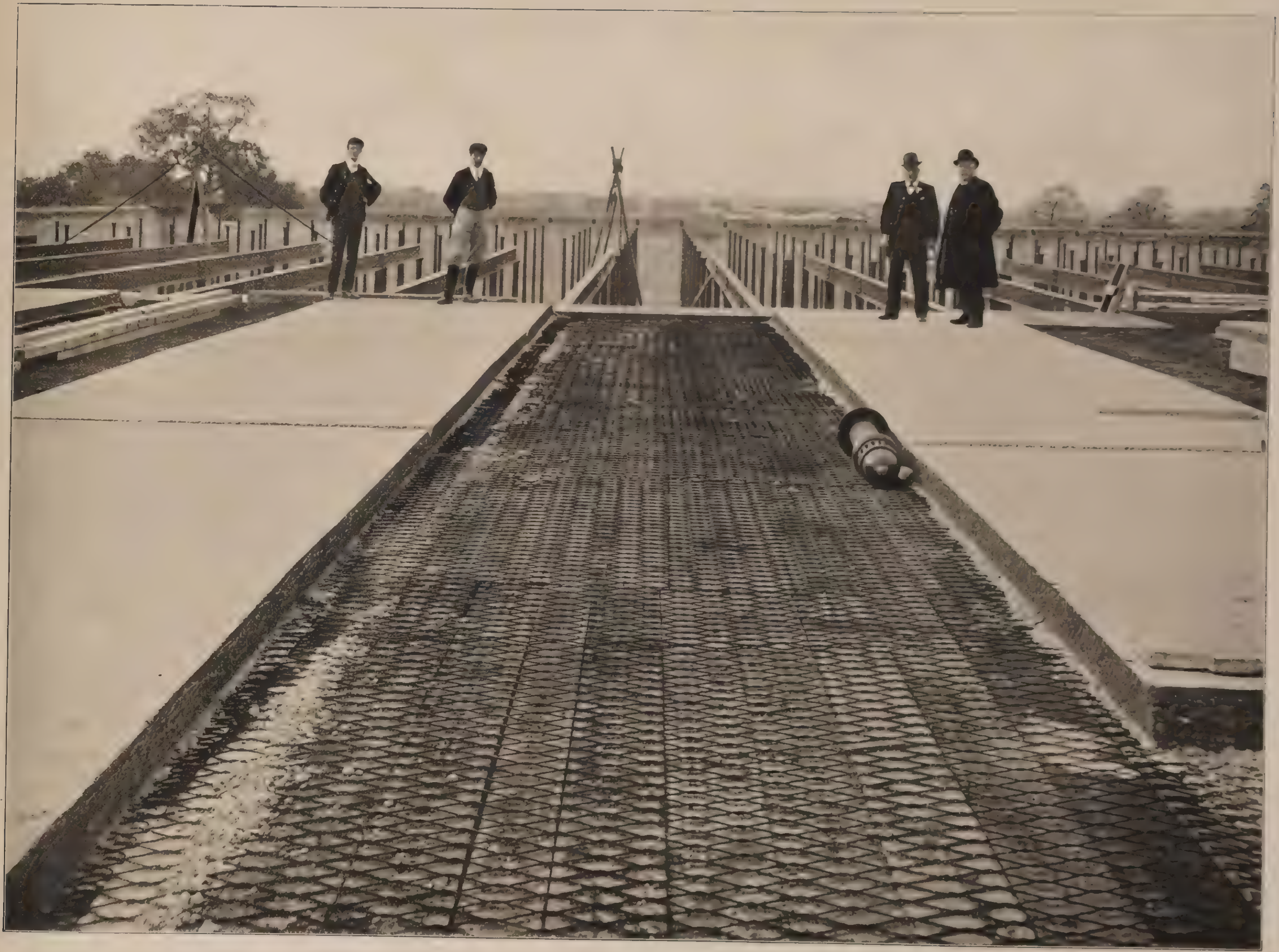
No. 5.—Showing Concrete Screeded to a fair face



New Service Reservoir, Ipswich Corporation.

Mr HAMLET ROBERTS, A.M.I.C.E., Engineer.

Showing Steelwork ready to receive Cover of Expanded Steel and Concrete.

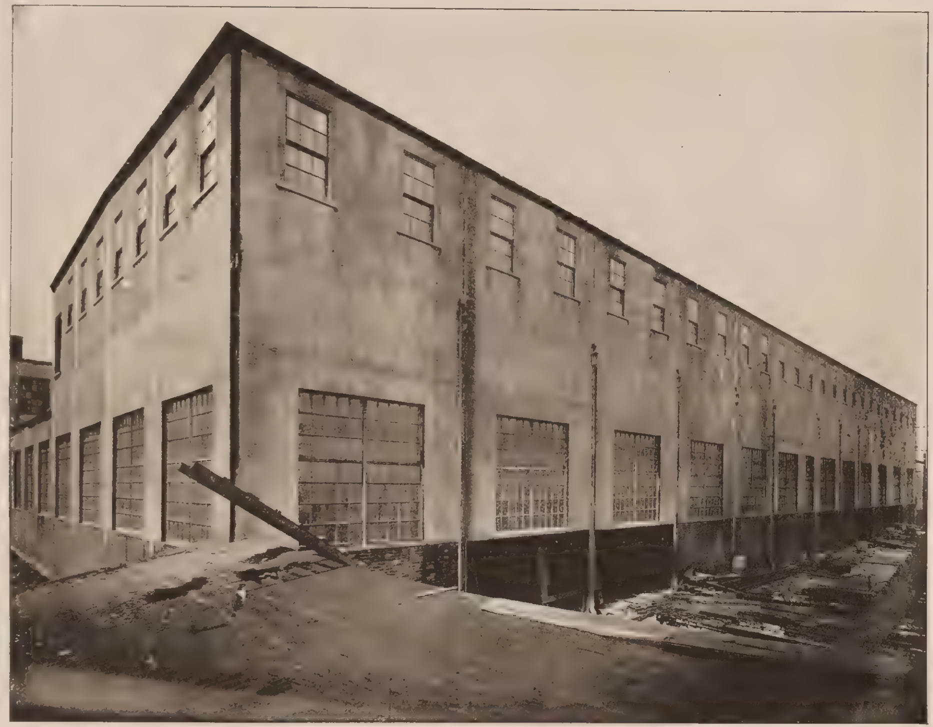


New Service Reservoir Ipswich Corporation.

Shewing Expanded Steel and Concrete Cover in course of construction.

Factory Construction.

DURING the past few years it has been demonstrated as a fact that a fire-proof factory building, for the average manufacturing establishment in this country, can be constructed at almost the same cost as the old style "tinder box." This has been accomplished by very simple methods. By using iron columns placed on slabs of reinforced concrete for foundations and the employment of good engineering skill, it is possible now to erect a factory building with plenty of light in the side walls as well as in the roof, and with a maximum amount of advantage in all directions. The best form of side walls for buildings of this general class may be described as the monolithic wall of steel and cement mortar. The steel should consist of small members, such as $\frac{3}{8}$-inch round or $\frac{3}{4}$-inch flat iron bars placed at 12-inch to 16-inch centres, upon which is laced a fabric of Expanded Steel lath, and upon this is built, with the plasterer's trowel, a slab of 2 inches to 3 inches in thickness. The roofs should be of steel framing, and should carry a slab of reinforced concrete on spans varying according to the general design, these spans ranging from 5 feet to 20 feet. If the roofs be flat enough, ordinary tar and gravel are quite desirable, or, if steep roofs are wanted, slate may be nailed directly to the concrete.

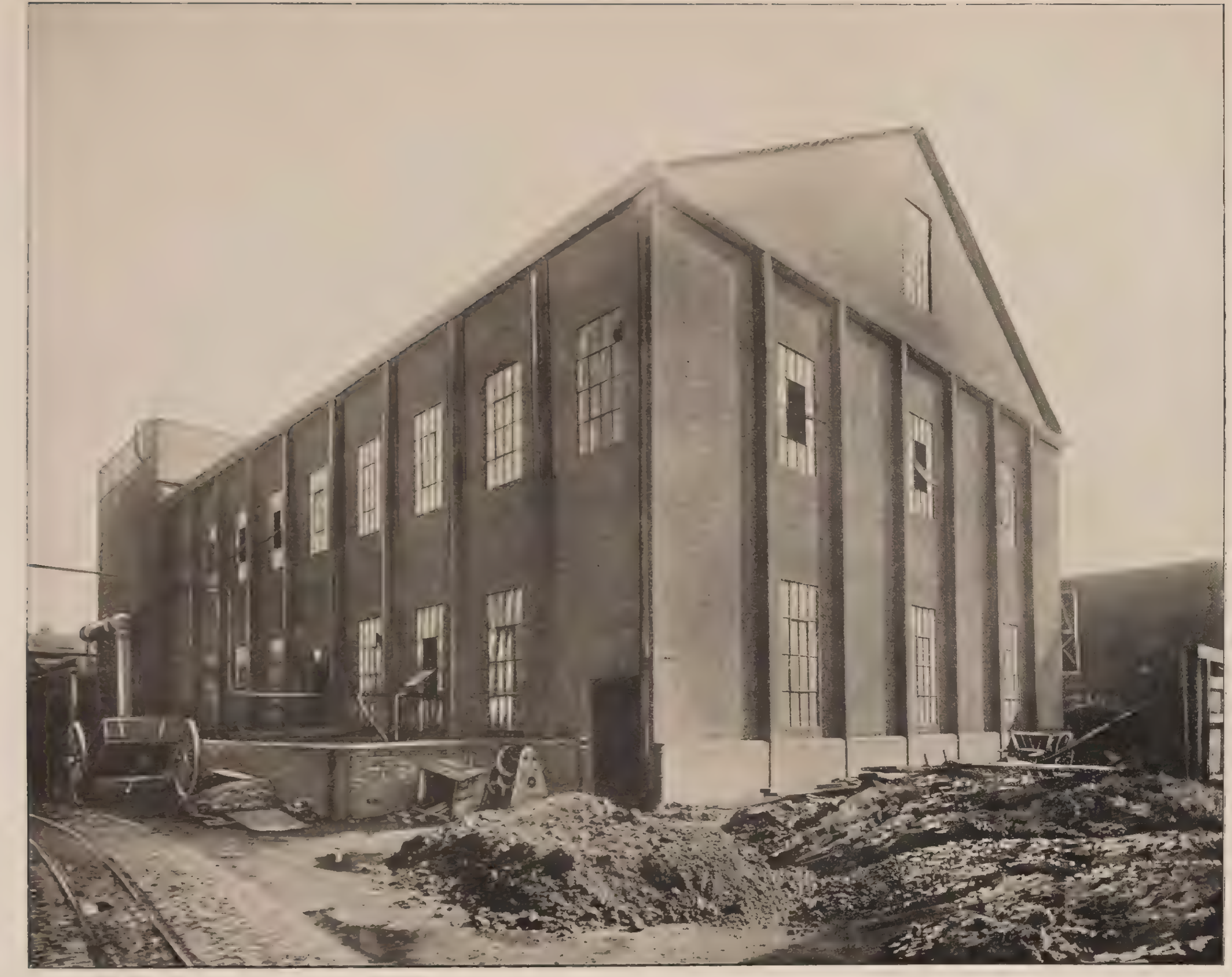


Upon this system there have been erected, in various parts of the world, entire factory plants, ranging from one to half-a-dozen or more buildings.

The first extensive plant built on this system was the Walker Soap Company's Factory at Pittsburgh, Pa. We show in this connection a view of one of the buildings constructed a year ago for the Dunmore Iron and Steel Company at Dunmore, Pa., by

Mr. Geo. Hill, engineer and contractor. Mr. Hill is now erecting a still more extensive set of shops at Elizabethport, N.J., for the Central Railroad of New Jersey. In each of these plants more than 250,000 square feet of Expanded Metal were used. We also show an illustration of a recently completed building for the Boston Bridge Works in Boston.

BOSTON BRIDGE WORKS.



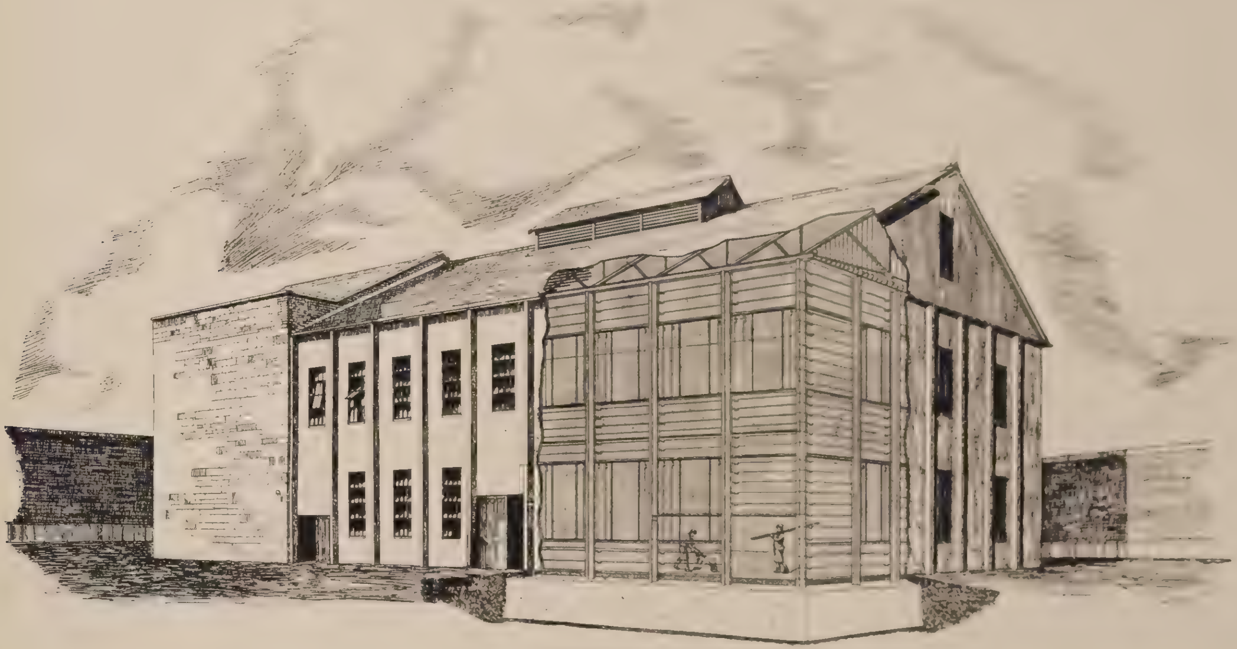
RETORT HOUSE AT DUBLIN GAS WORKS.

Steel Framework, Expanded Steel Lathing and Cement Plaster Construction.

The illustrations shew a fair example of what can be done by the judicious employment of steel skeleton framing and Expanded Steel lath and plaster filling. The illustration is a photograph of a retort house built by us in Dublin three years ago. The building is 86 feet long, 56 feet wide, and 32 feet high to the eaves. A skeleton building was first erected, and then the whole covered in and encased with Expanded Metal lathing and cement plaster. The walls are formed of 3 inches of plaster laid on our Expanded Metal lathing, which was tied with copper wire to horizontal tension rods, $\frac{3}{8}$-in. diameter, stretched 12 inches apart from stanchion to stanchion. This system of construction gives, when finished, a structure light (and therefore requiring but slight foundation work), strong, and economical, and in every respect suited to the purpose for which it is required. The framing and plaster lend themselves to plain or ornamental work, as may be desired, and in the Dublin building the walls were finished smooth inside, and rough cast on the outside. It is obvious that the system, with but few alterations in details, can be applied in many thousands of cases where cheapness, small deadweight, etc., are of primary consideration.

It is interesting to note that no inflammable material of any description was employed, the framework, sashes, doors, etc., all being of steel, and the roofing slates fixed to steel purlins by lead cleats.

Similar buildings have been erected in different parts of the United Kingdom.



SHEWING STEEL SKELETON.

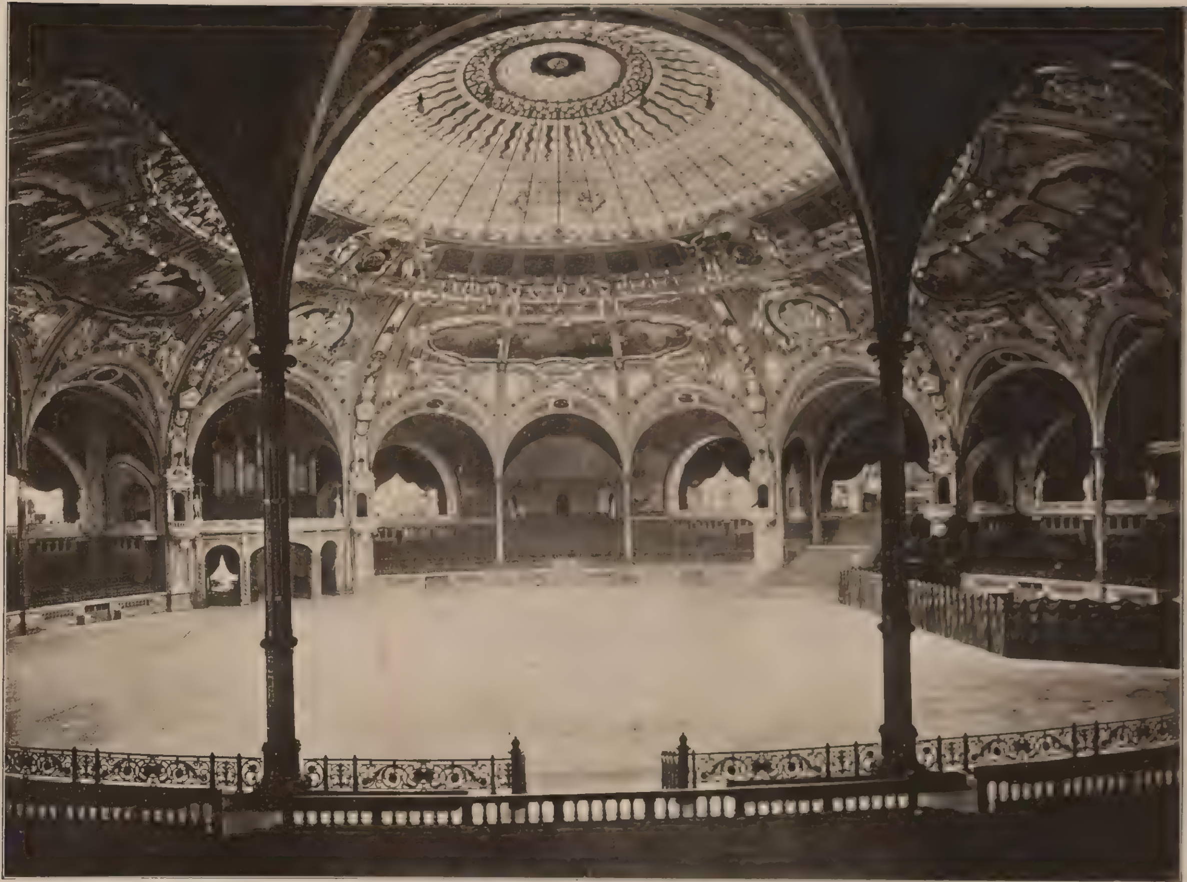
Expanded Steel in Exhibition Buildings.

IN the Columbian Exposition in Chicago, in 1893, Expanded Steel was largely used, and, it was so used in these buildings that a large portion of it was visible to the eye of the visitor. It was in the days when Expanded Steel was primarily known as fencing material, and hence miles of railings around the galleries of the main buildings were built of wood frames to which were attached sheets of Expanded Steel. A small amount of it was used as a lathing in the buildings of a more permanent character, in which case, of course, it was hidden.

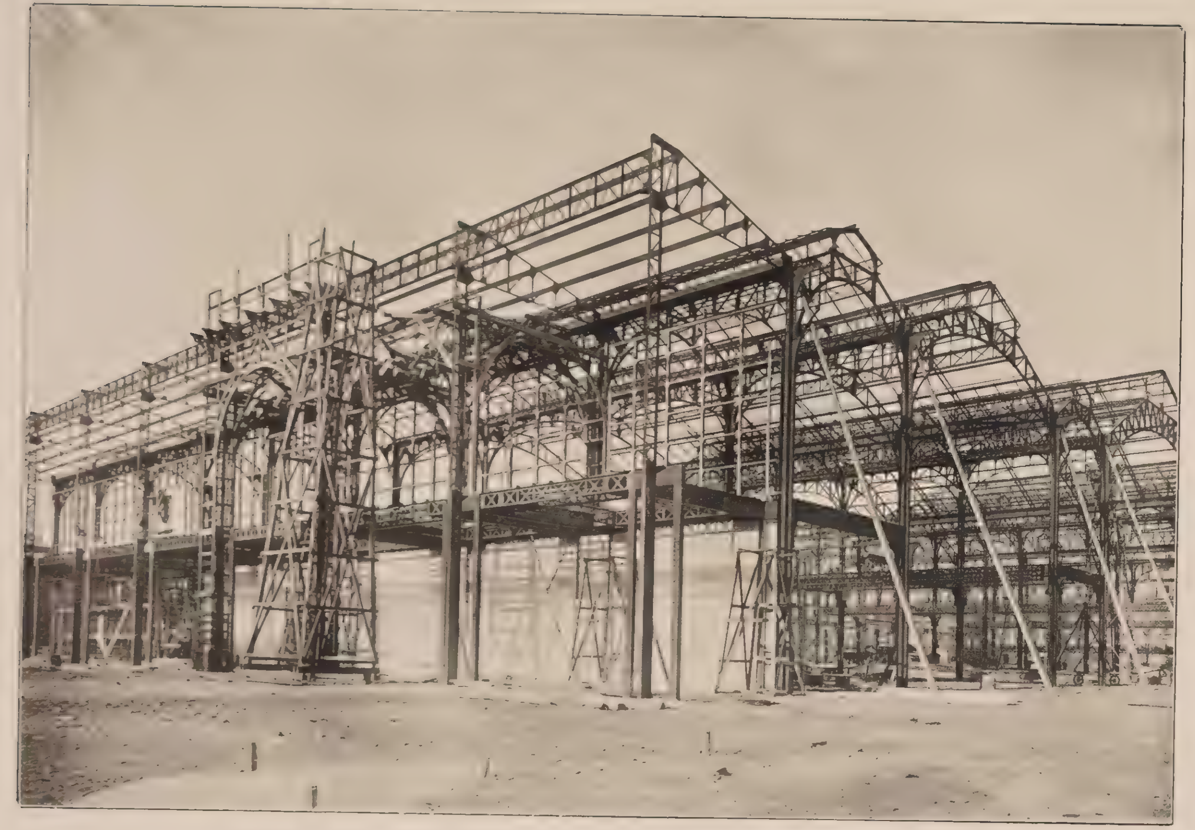
In the Paris Exposition of 1900, more than 1,000,000 square yards of Expanded Steel were used, and probably all but a few thousand yards of it was hidden in the walls, floors and roofs of the buildings. It is true that more or less of it was used in railings in certain portions of the buildings. A large quantity of it was used in the construction of concrete bridges which crossed the River Seine, notably the Pont Alexandre III, an illustration of which is given under "Bridges."

In the Buffalo Exposition the same facts occur as in Paris. Many thousands of yards of material were used, but practically all was hidden. Scattered throughout the grounds at Buffalo were scores of small fanciful pagodas and public park seats. In the erection of these and similar structures Expanded Steel was used as the bonding material for concrete work, and very ornamental and universally admired results were secured.

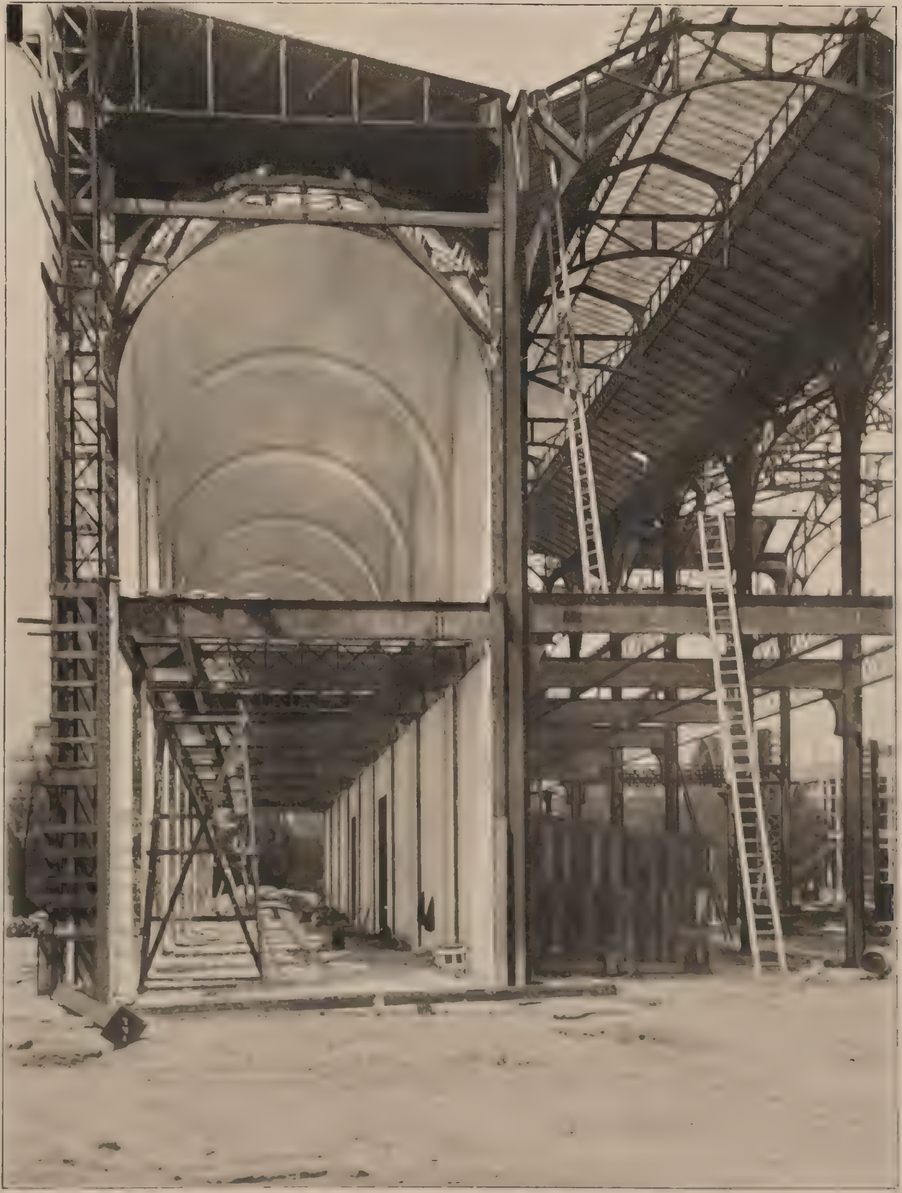
In the Glasgow Exhibition of 1901, the Cork Exhibition of 1902, the Earl's Court Exhibitions, and in almost every Exhibition Building that is erected, our material is used for innumerable purposes. The following series of photographs of a few of the buildings of the Paris Exhibition of 1900, the Cork Exhibition of 1902, the Delhi Durbar, &c., illustrates the adaptability of Expanded Steel, and its many uses in this class of work.



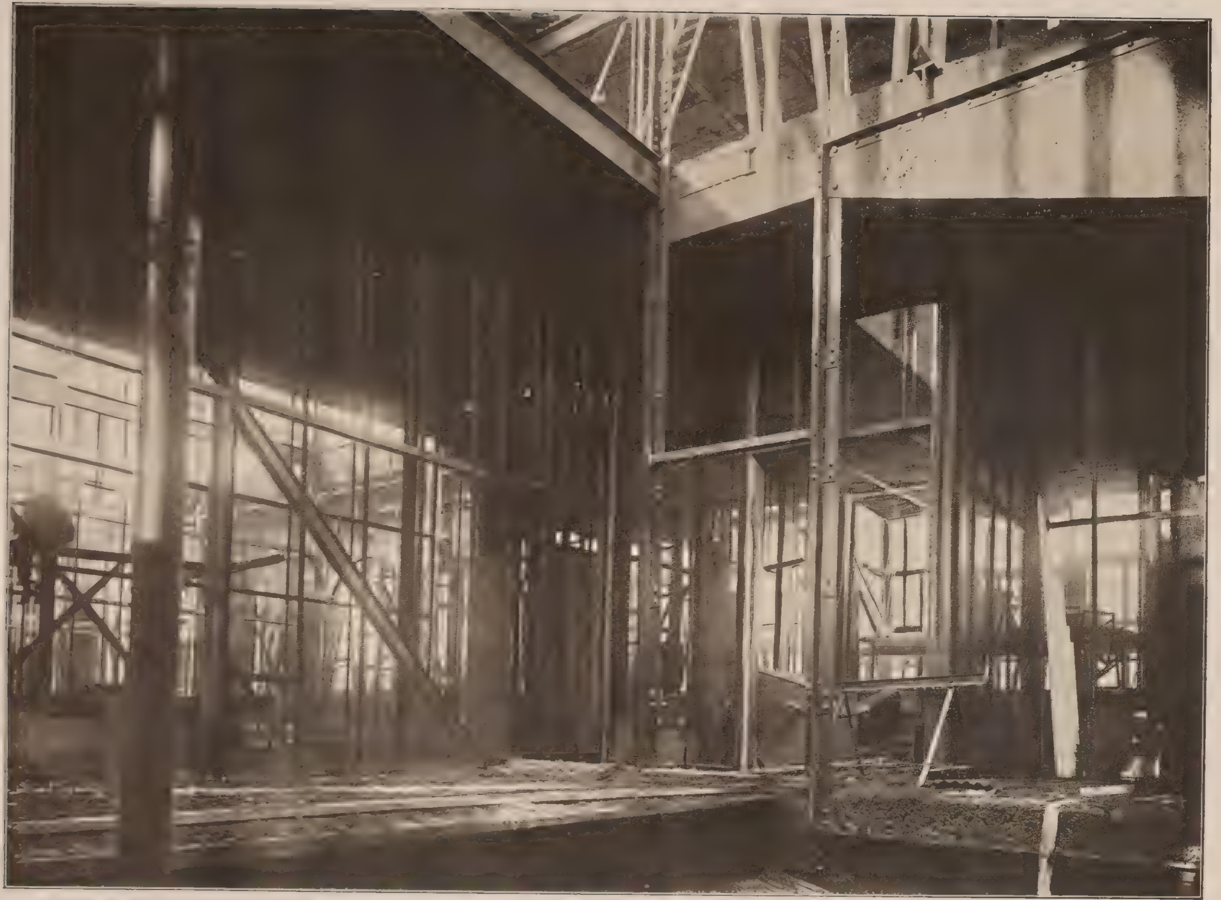
SALLE DES FÊTES (INTERIOR). PARIS EXHIBITION, 1900.



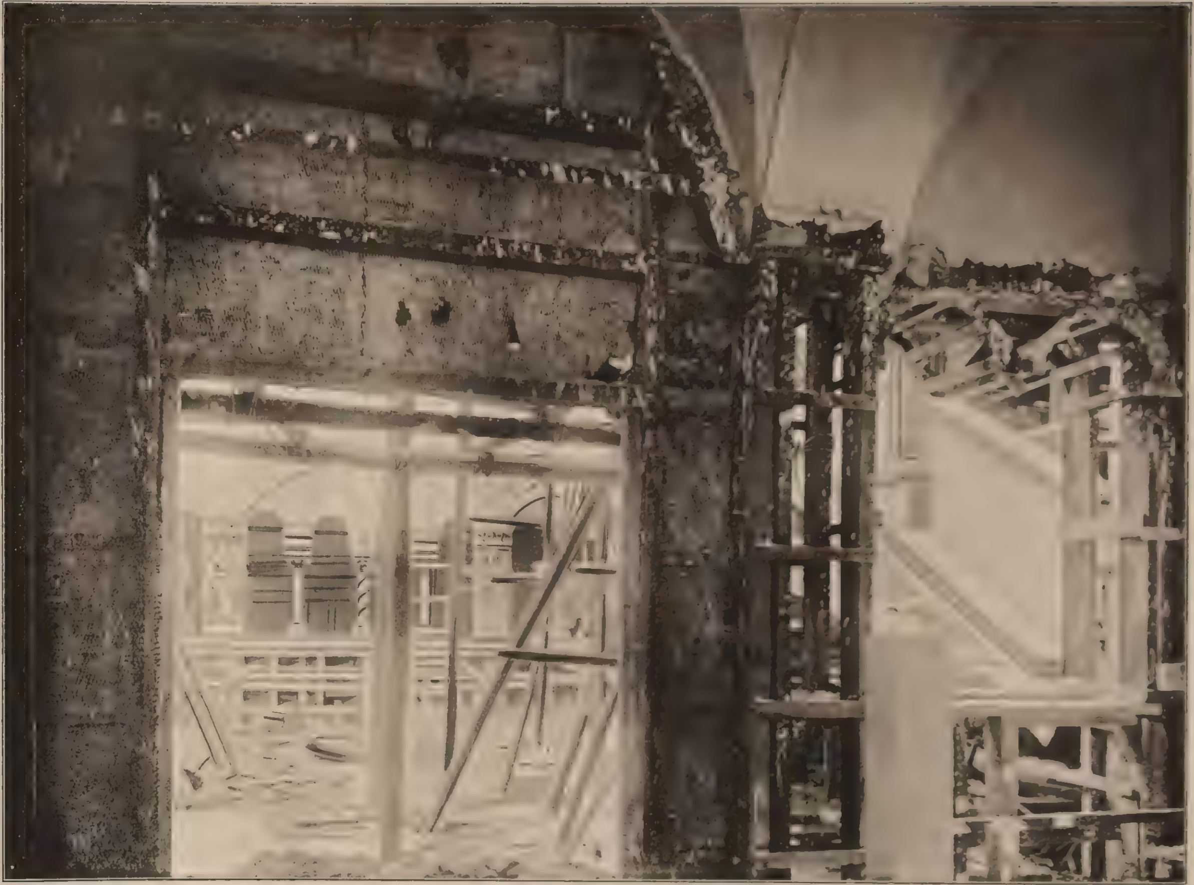
MINING AND METALLURGICAL BUILDING, PARIS EXHIBITION, 1900,
Before covering with Expanded Steel Lathing and Plaster.



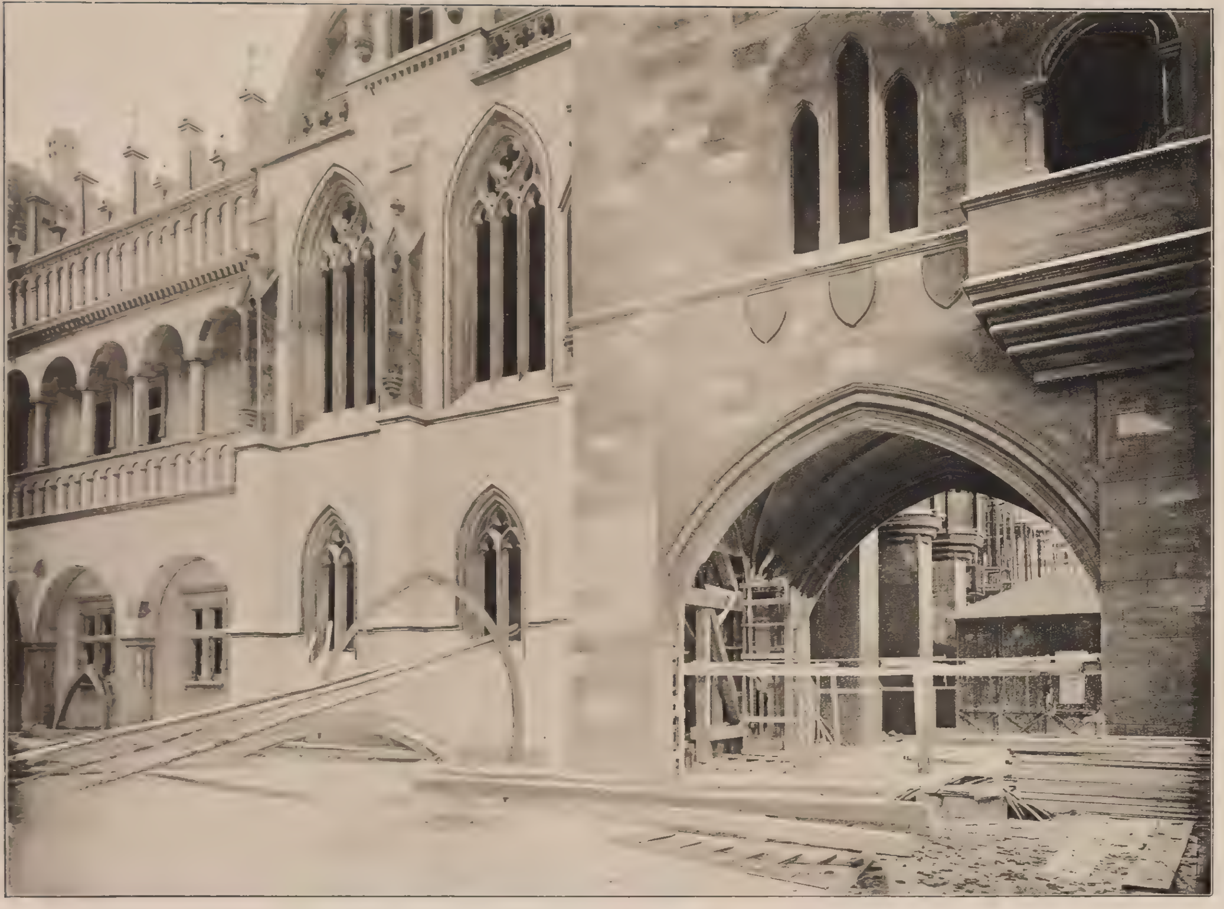
MINING AND METALLURGICAL BUILDING, PARIS EXHIBITION, 1900.
During Plastering upon Expanded Steel Lathing.



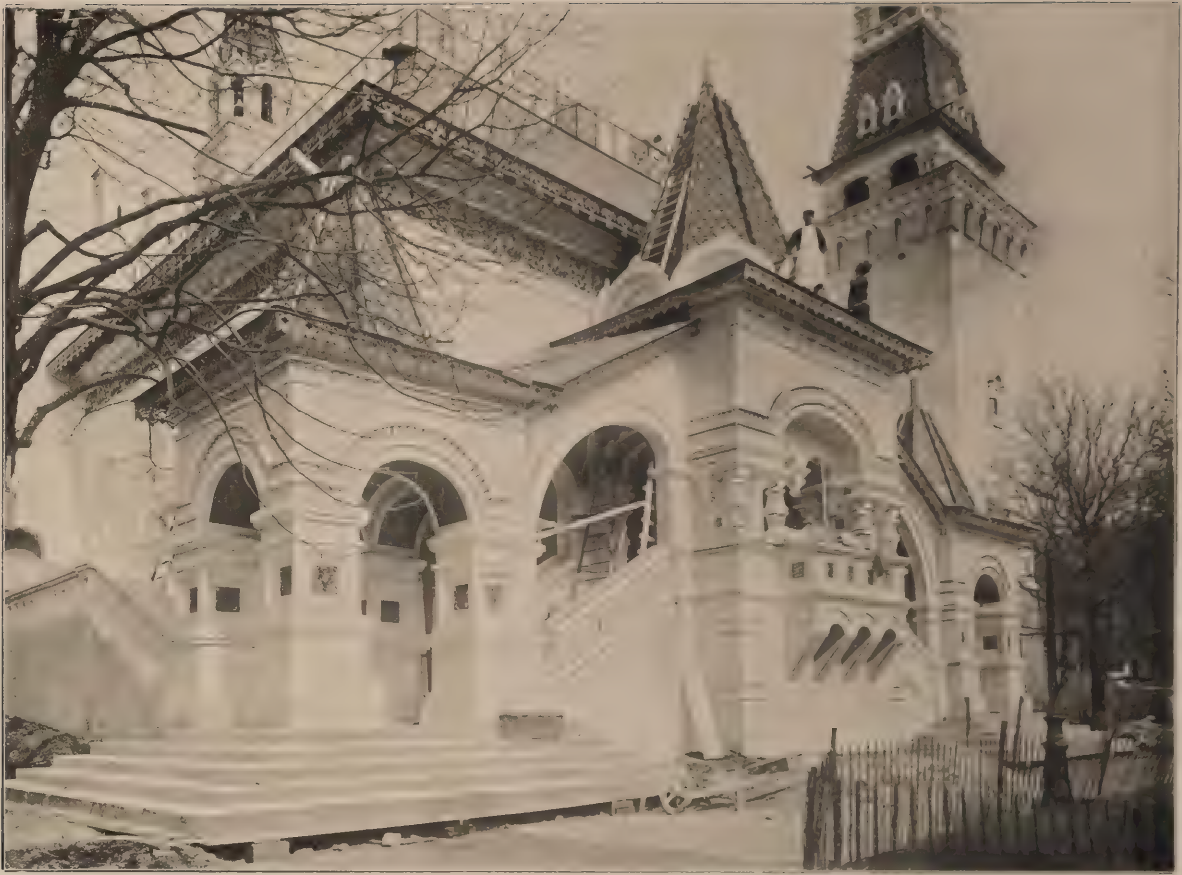
BRITISH PAVILION, PARIS EXHIBITION, 1900.



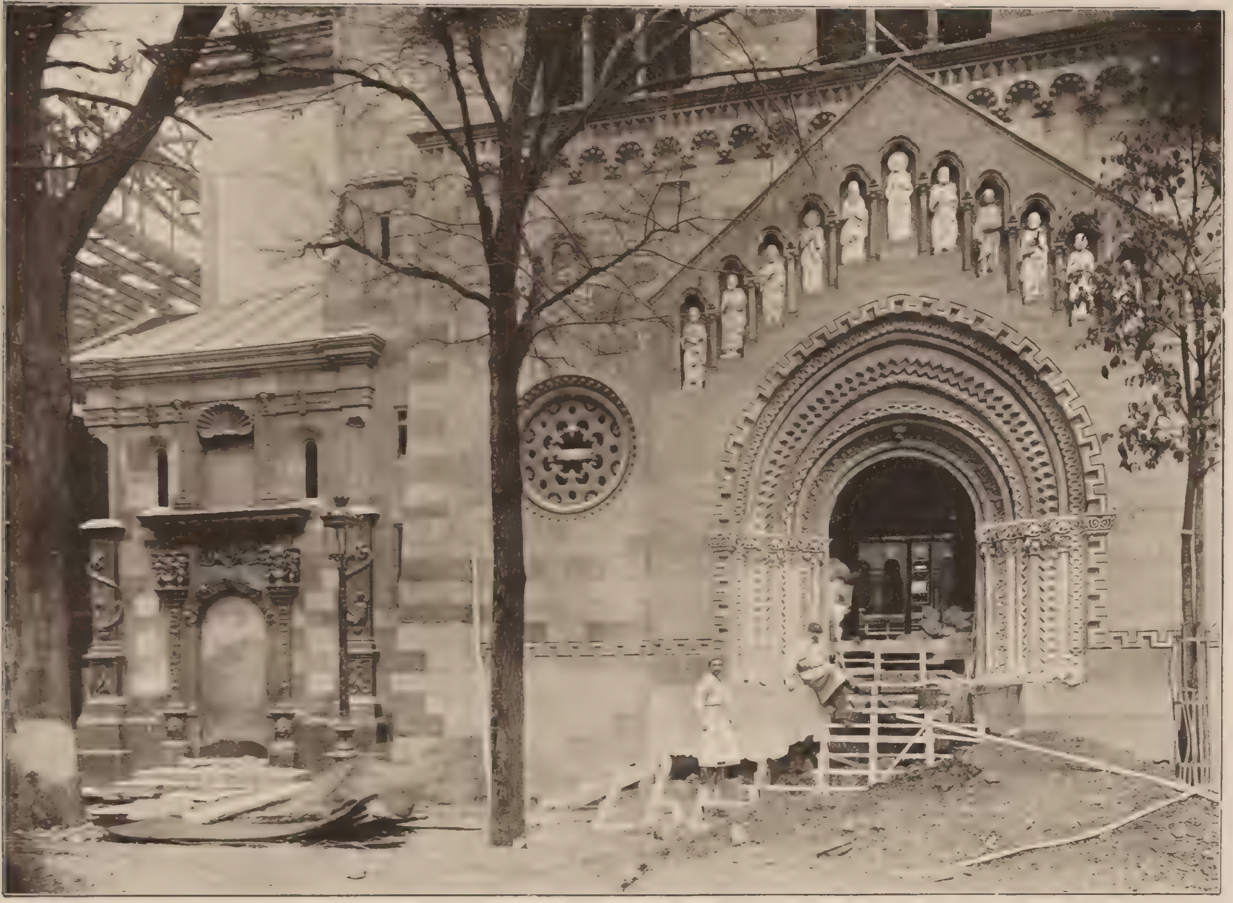
HUNGARIAN PAVILION, INTERIOR, PARIS EXHIBITION, 1900.



ROYAL HUNGARIAN PAVILION, PARIS EXHIBITION, 1900.

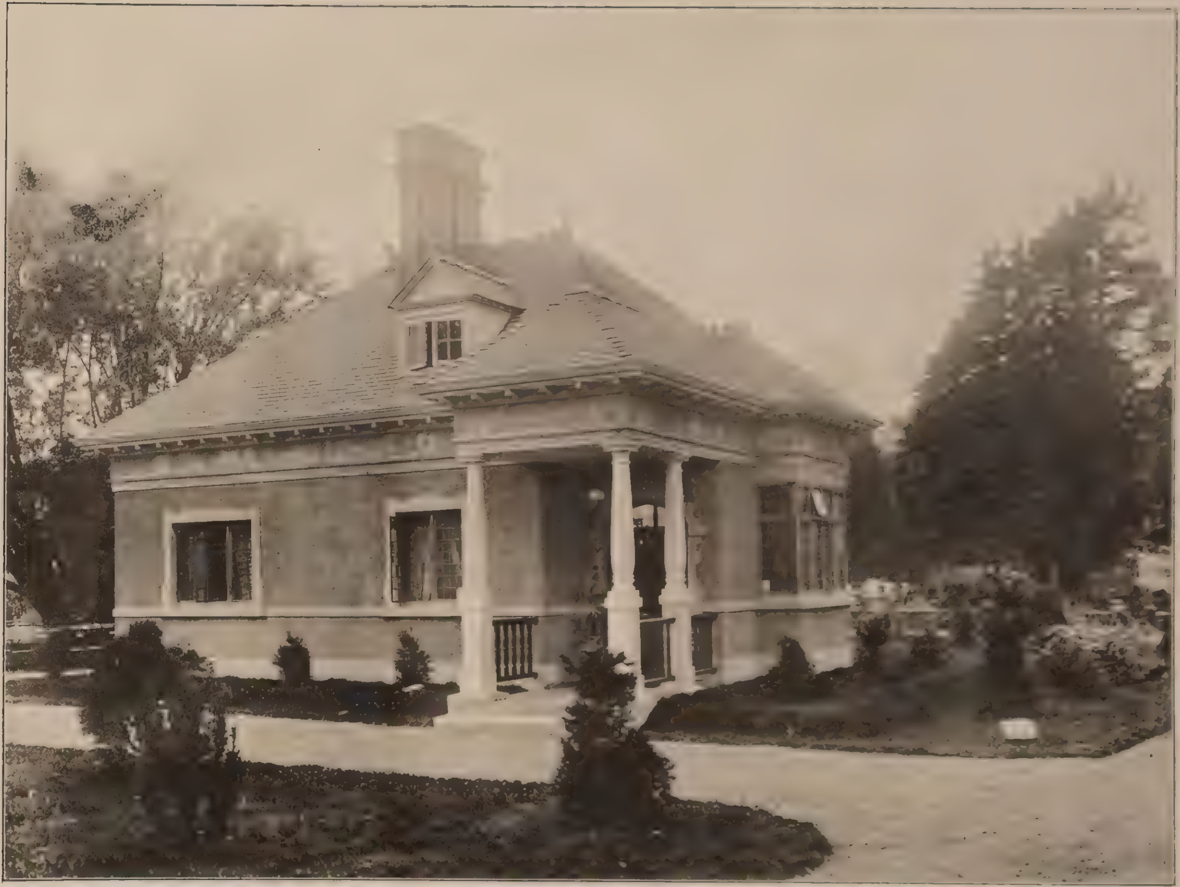


IMPERIAL RUSSIAN PAVILION, PARIS EXHIBITION, 1900.
Carried out entirely in Expanded Steel Lathing and Stucco.



ROYAL HUNGARIAN PAVILION, PARIS EXHIBITION, 1900.

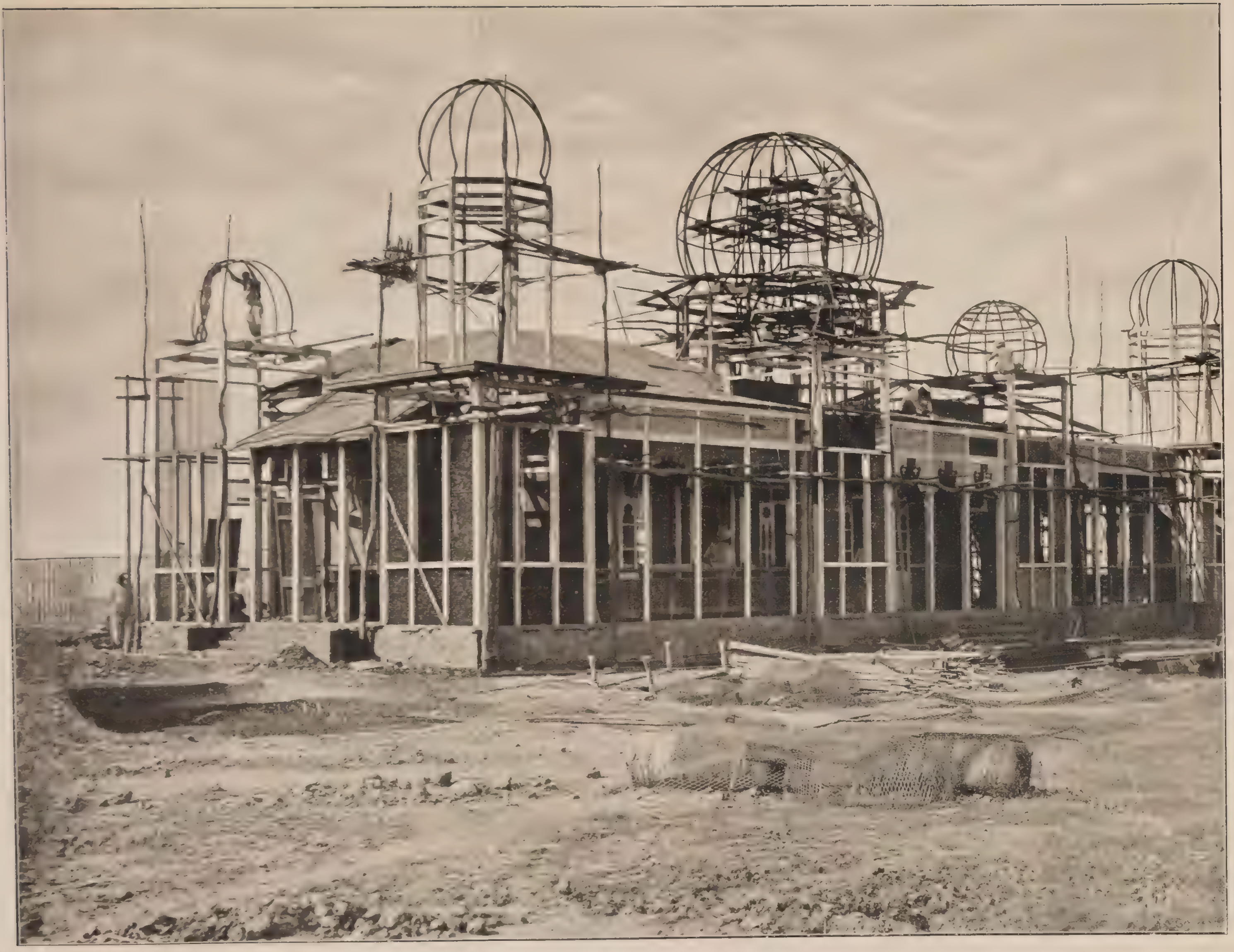
A remarkable example of decorative exterior work upon Expanded Steel Lathing.



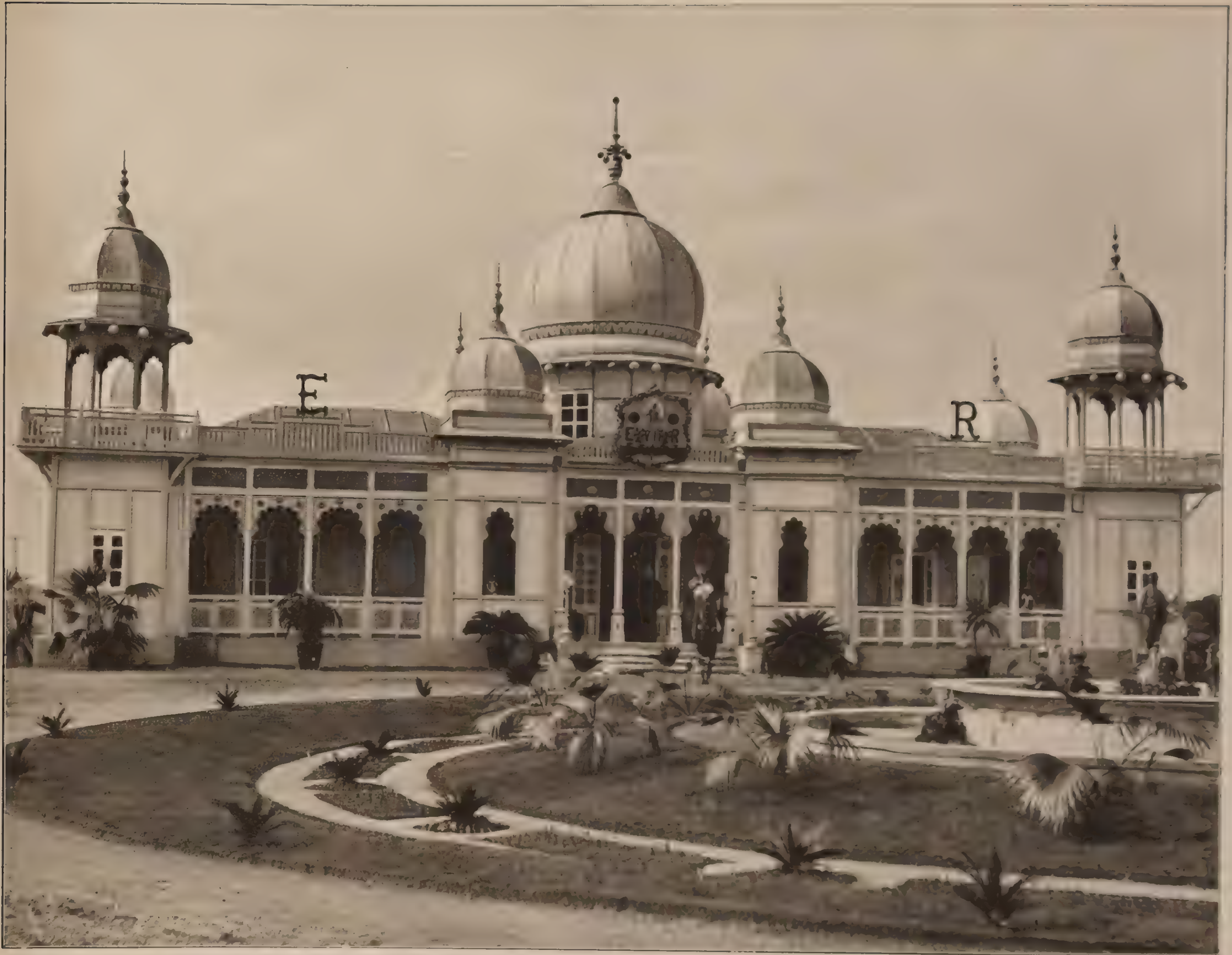
THE CORK EXHIBITION, 1902.

PRESIDENT AND LORD MAYOR'S PAVILION
Wood Studding, Expanded Steel Lathing and Cement Plaster.

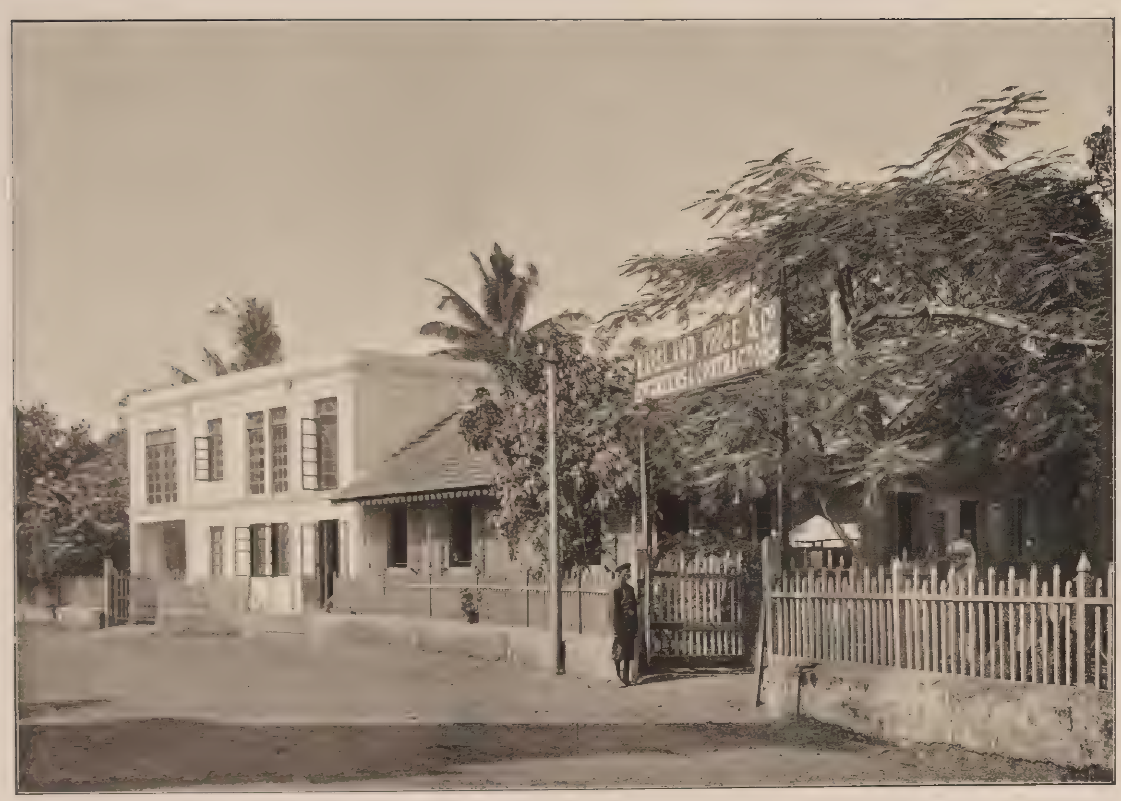
ARTHUR B. HILL, Esq., F.R.I.B.A., Architect



Delhi Durbar.—Skeleton Pavilion for H. H. the Gaikwar of Baroda. Expanded Steel Lathing and Plaster Construction.

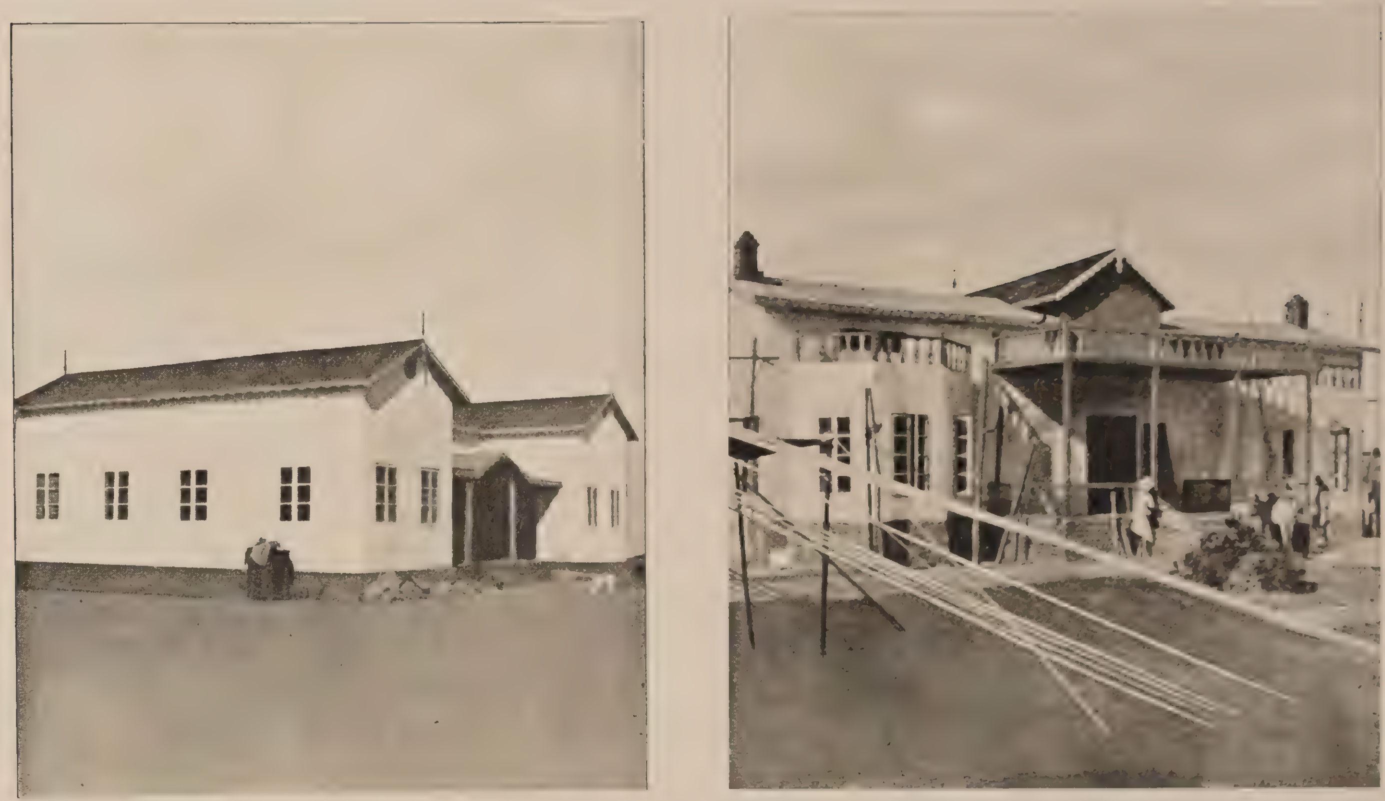


Delhi Durbar.—Finished Pavilion for H. H. the Gaikwar of Baroda. Expanded Steel Lathing and Plaster Construction.

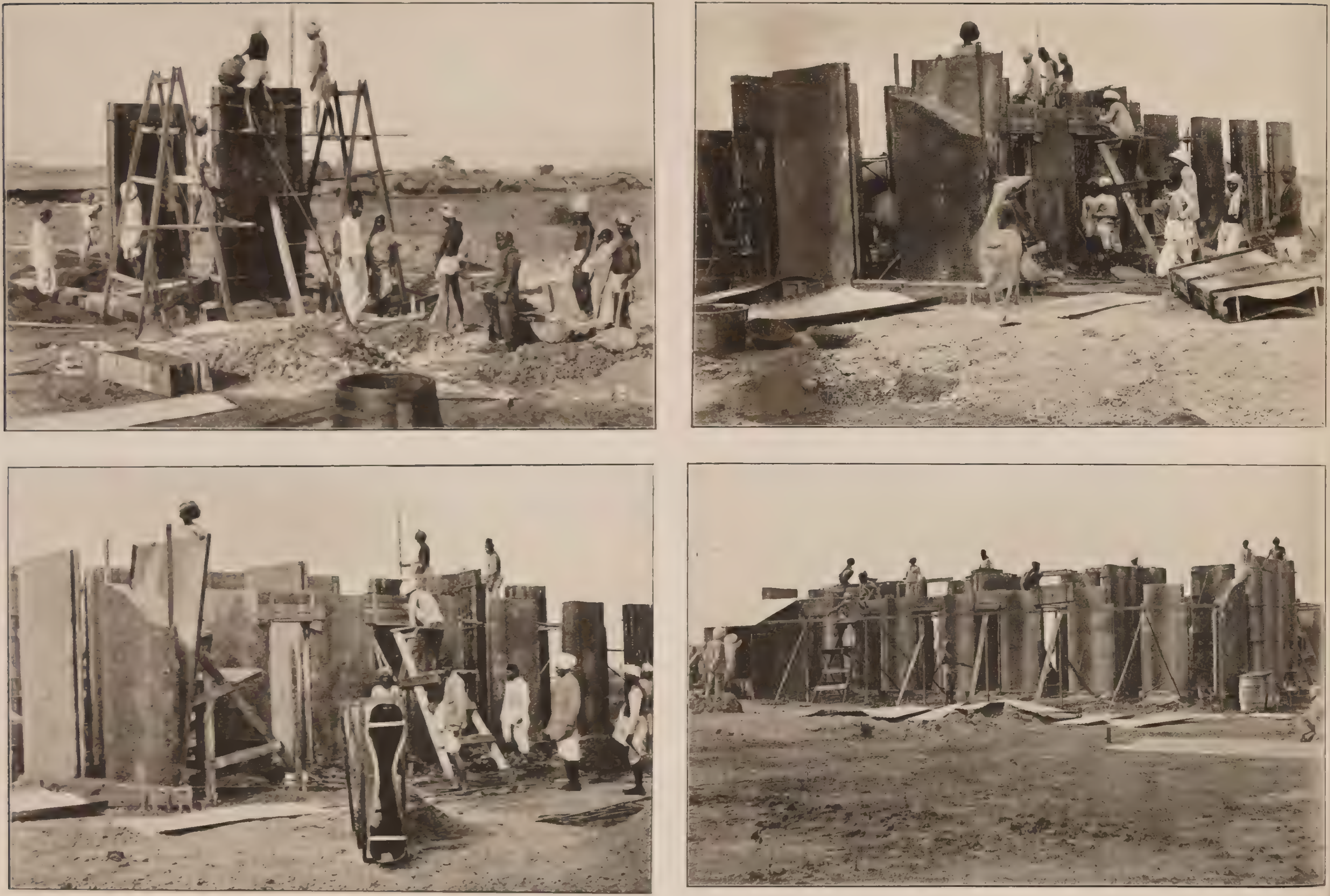


Officers' Premises, Bombay, India.

Steel Framework, Expanded Steel, Concrete and Plaster.

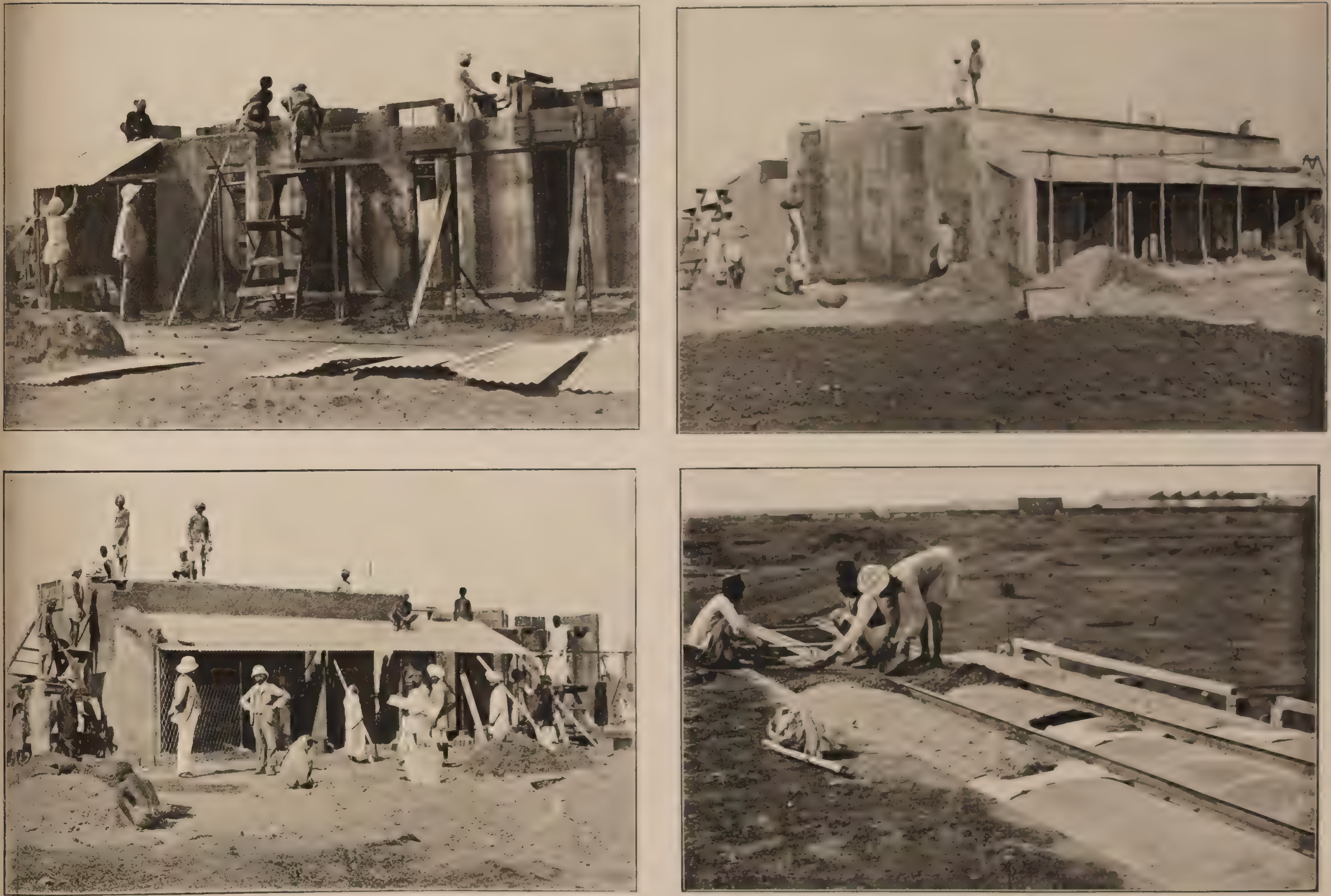


Expanded Steel and Plaster Buildings,
Delhi Durbar.



WORKMEN'S DWELLINGS.—BENGAL AND NAGPUR RAILWAY.

EXPANDED STEEL AND CONCRETE CONSTRUCTION.



WORKMEN'S DWELLINGS.—BENGAL AND NAGPUR RAILWAY.

The New Central Bridewell Gaol, Dublin.

AN interesting novelty in prison construction was adopted in The New Central Bridewell Gaol, Dublin, constructed two years ago by Messrs. Lowry, Contractors, of Belfast, for the Commissioners of Public Works. The whole building is of Concrete, built *in situ*, and the floors, roof and stairs were further strengthened by the use of Expanded Steel in conjunction with the Concrete. The work was expeditiously carried out by means of temporary wood centering, which was erected over the whole site at once in two feet courses. Thus, with the bottom course of centering erected, the first course of walling was laid and allowed to set; then the centering was struck, re-erected two feet higher, and the next course laid, and so on. This system of construction has no equal for prisons, banks, strong-rooms, bonded stores, treasure houses, etc., as it is without doubt, far more difficult to cut a hole in granite and cement concrete than to remove a brick or stone from an ordinary wall.

This system is applicable to ordinary requirements for warehouses, stores, and buildings of the heavier type, and it is obvious that the cost is low when compared with an ordinary ashlar wall, as chippings, broken brick, river ballast, slag and similar material can be used as aggregate for the concrete, which necessarily makes the cost very much lower than hewn stone work. The cost may be further reduced by the use of Expanded Steel in the outside walls, as even greater strength is then obtainable with a less thickness and weight of concrete.

It will be seen from the illustration that the centering can be easily devised to give any wished-for ornamentation, and if the parapet walls are made sufficiently high, the roof can be used for parade ground, storage purposes, water tank, etc., etc., and in the case of schools, flats, artisans' dwellings, etc., for play grounds, drying grounds, etc., etc.

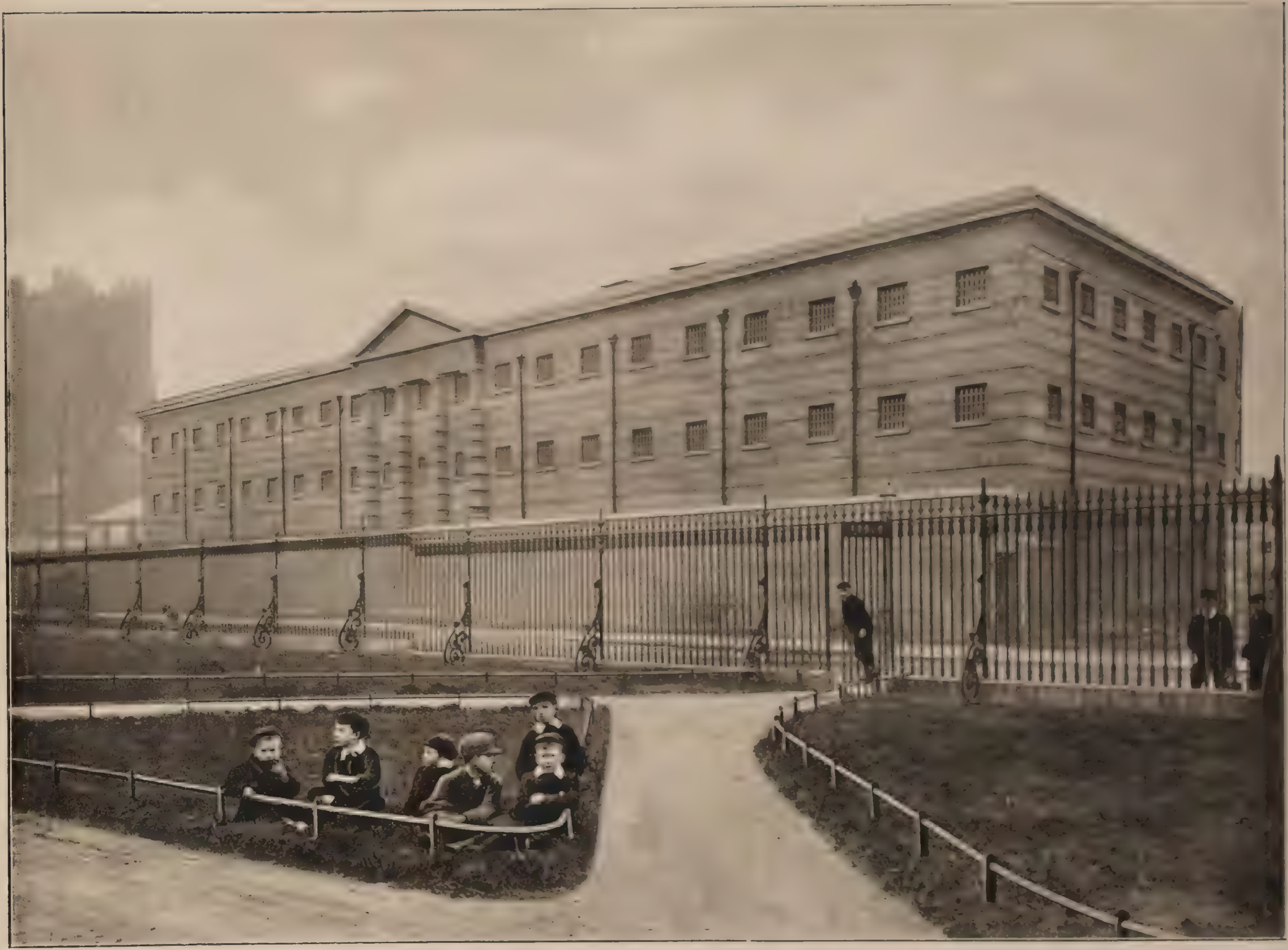
Schools, Hospitals, Asylums, Hotels, Flats, etc.

THIS system is admirably adapted for school buildings, hospitals, asylums, hotels, flats, offices and similar large buildings where there are numbers of people dwelling under one roof and where an extensive fire would probably result in serious loss of life.

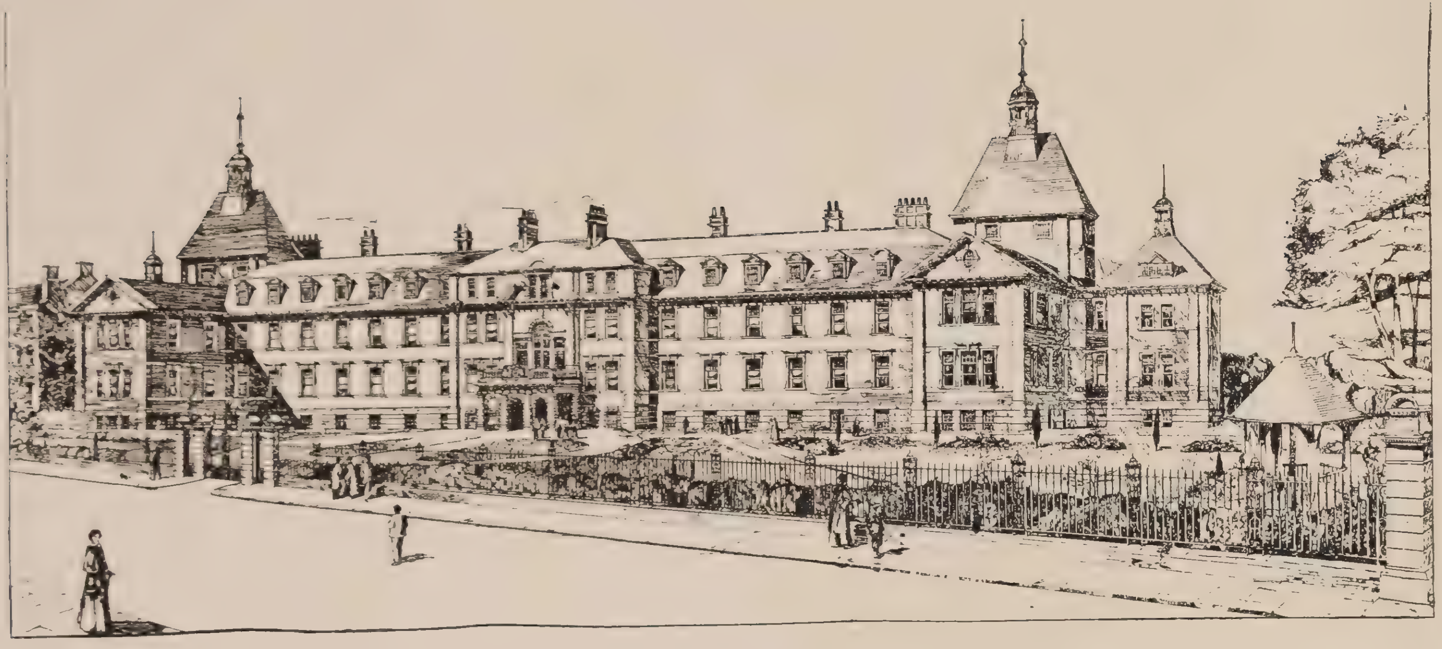
Under this system of construction any outbreak of fire that may occur can, with practical certainty, be confined to the room or floor in which the fire may originate; and inmates on the floors above and below the seat of the fire would be immune from the risks to which they are exposed in buildings that are not constructed on fire-proof principles. Another point is that steel and concrete construction is far more sanitary than wood and plaster work, and it can be more easily cleansed, and kept free from dust, vermin, etc.

The Architects to the Aberdeen School Board, the South Shields School Board, the Gateshead School Board, and many others eminent in their profession have adopted this system of flooring and roofing in their designs, and it cannot be too strongly advocated for similar buildings.

The Architects for the London, Poplar, Guy's, Italian, St. John's Wood, St. Thomas's, Chester, Colinton, Paisley, Stirlingshire, Birmingham, Victoria Eye and Ear, Dublin, etc., etc., Hospitals, and for the Chadwell Heath, Claybury, Hanwell, St. Albans, Bexley Heath, Downpatrick, Middlesex County, Winchester, West Riding, Yorks, Bracebridge, etc., etc., Asylums have insisted upon the fireproofing of their various works, and there can be no question that the extra expense thus incurred to ensure the public safety is amply justified, and the example that they have set in this respect cannot be too highly commended.



THE NEW CENTRAL BRIDEWELL GAOL, DUBLIN.
THE COMMISSIONERS OF PUBLIC WORKS.
Concrete throughout, with Expanded Steel in the Floors, Roof and Stairs.



Royal Victoria Eye and Ear Hospital, Dublin

Messrs. CARROL & BATCHELOR, Architects.

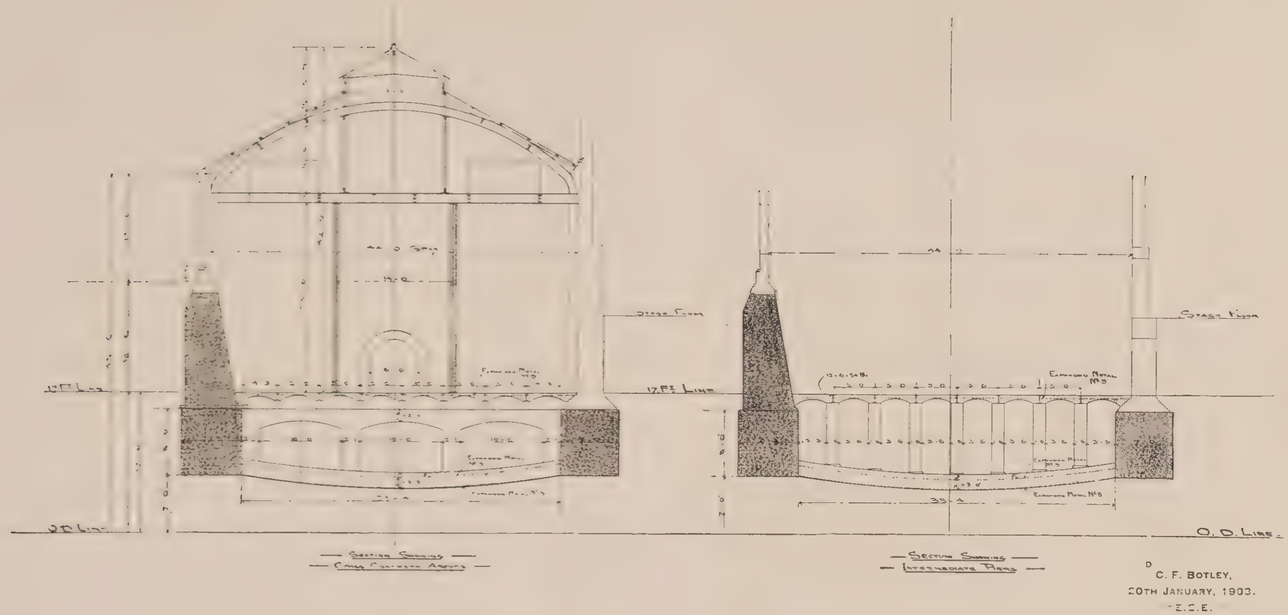
Floors, Partitions and Ceilings.

Howth Bailey Lighthouse.

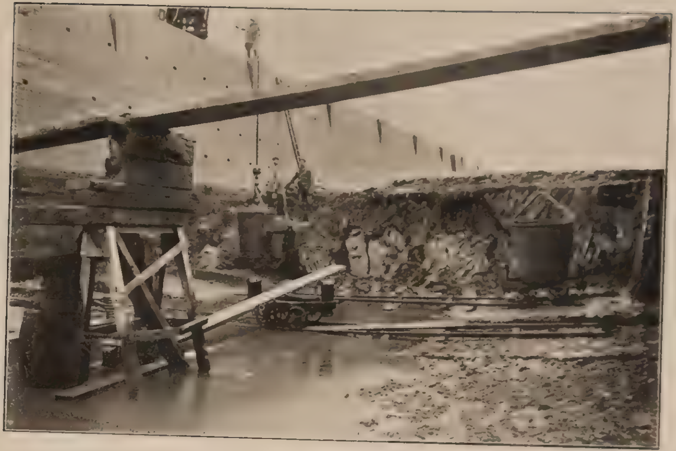
Floors.

HASTINGS AND ST. LEONARDS GAS CO.

GLYNE WORKS.

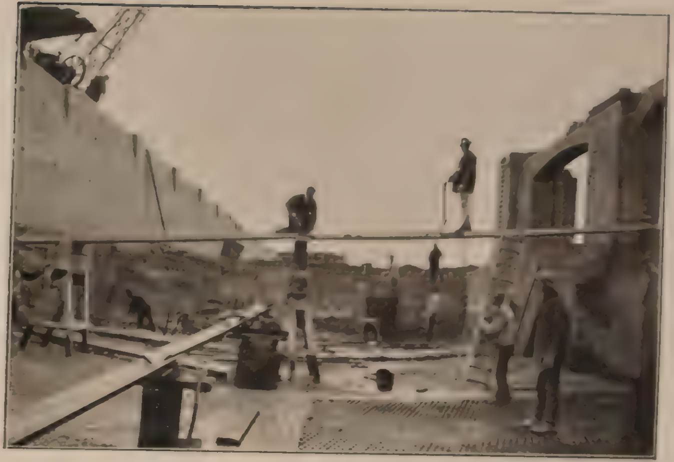


SECTIONS OF COAL STORES.



NO. 1.

In this photo, the method of excavating the water tanks is clearly shown, the crane [illegible] behind the Retaining Wall. The difficulty, owing to the extremely bad weather, [illegible] this view, the centre of the invert being covered with water. The staging in the [illegible]

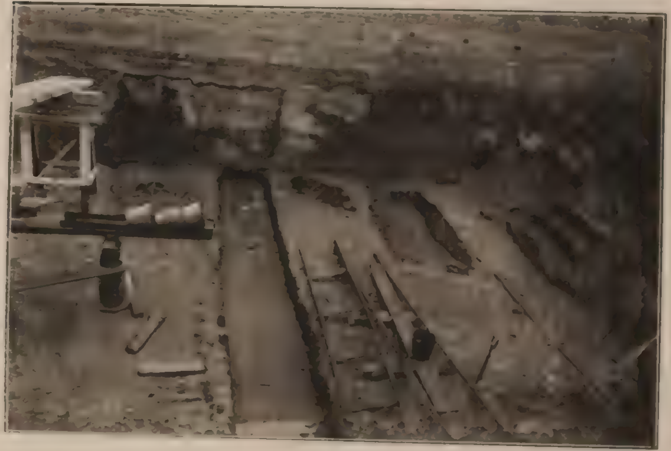


NO. 2

[illegible]

NO 3

Unfortunately this photo. is "fogged" but otherwise it gives an excellent ide[illegible] which the men are placing in position on the very thin layer of concrete. The view [illegible] to the Lift House, the Retaining Wall rising on the right hand. One concr[illegible] timbering for the same being in pos[illegible]



NO. 4

[illegible]

NO. 5.

[illegible]

Owing to extension of business, the Hastings and St. Leonards Gas Company have now under construction new Works for the supply of light and power to Hastings and district. The Works are situated at Glyne Gap on a site of about 20 acres, alongside the main line of the L. B. & S. C. Rly., midway between West Marina and Bexhill stations. In these Works advantage is naturally being taken of all modern improvements in construction and manufacture, and thus re-inforced concrete work or Expanded Steel in concrete has been brought into use.

For instance, the construction of the coal stores appears particularly interesting. Taking advantage of the contour of the ground and other circumstances, it was decided to provide the necessary water storage under the coal stores, and the foundation concrete footings of the retaining wall on the one side and of the retort house on the other, as will be seen from the drawing, materially assist in this connection. In designing the water storage tank it was important to obtain as much capacity as possible within the area. Hence, it was undesirable to have very thick concrete over the bottom, although, owing to the nature of the foundation (especially at one end), and the loading from the coal stores, considerable strength was necessary. The coal stores floor, which may have to carry half a ton per square foot, is carried by girders and re-inforced concrete arches (No. 9—$\frac{3}{16}$ ins. × $\frac{1}{8}$ ins.—3 in. mesh Expanded Steel being used) on cross concrete arches at 21 ft. centres and intermediate piers of blue bricks. (These piers are not shown in the views). The cross concrete arches also serve as struts to the retaining wall, and the floor is kept up rather higher in the centre so as to resolve some horizontal thrust. As the weight from the coal stores will be concentrated at the arches and piers, footings of 3 ft. 9 ins., and 3 ft. wide respectively, with Expanded Steel in the bottom side, have been provided. No. 10 and No. 9 Expanded Steel has been used for this purpose in accordance with the nature of the ground, and the thickness of these footings is 2 feet, or, in case of very bad places, a little more. The bottom of the water tanks is really an invert, and Nos. 8 and 9 Expanded Steel has been used on the underside in concrete of about 9 inches thick. Finally, the concrete work has been rendered with cement and, although the tanks have not yet been brought into actual use, it is believed they will prove sound and in every way satisfactory. The No. 1 Section will have a capacity of about 250,000 gallons, the overflow line being 6 inches above the top of the cross concrete arches.

The photographs in conjunction with the drawings will make this description rather more explicit. The concrete used is composed of shingle or beach with Portland cement and some sand. The proportions generally running about 6 to 1, varying according to the nature of the beach.

Mr. Chas. E. Botley, M. Inst. C.E., the Engineer and Manager of the Company, is responsible for this work, the drawings for which have been prepared and the work carried out under the supervision of his Chief Assistant, Mr. C. F. Botley, Assoc. M. Inst. C.E.

NO. 6.

This view is taken from the retaining wall looking down into the water tanks. It gives a good idea of the openings provided in the sides of the retort house and lift house, many of which may be eventually filled up. It will also be seen that the water tanks already are partly filled with water. This was due to the exceptional rains at the beginning of September, which practically caused this work to be stopped for over a month. The cross arch pieces are 21 feet centres, and not only form struts for the retaining wall, but also play a part in carrying the floor of the coal stores.

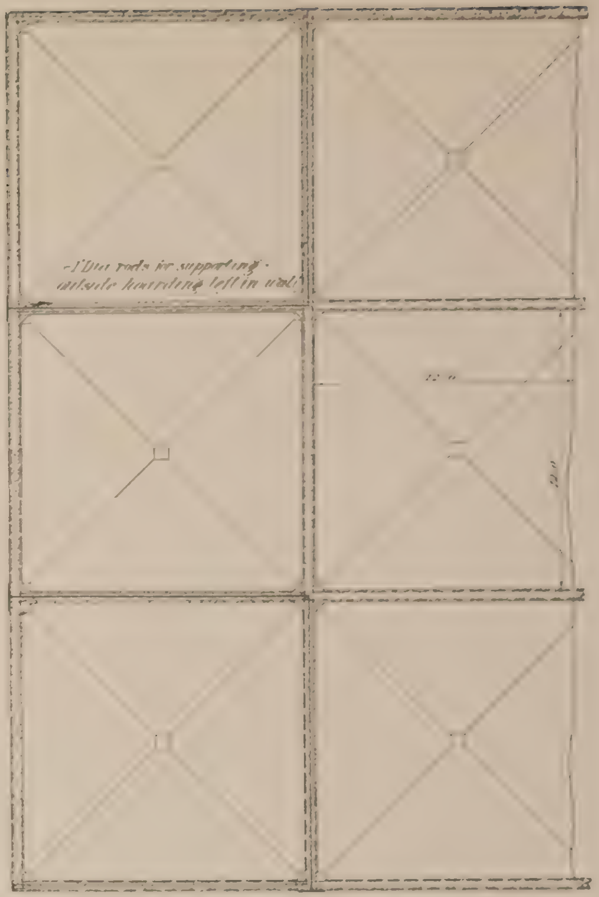
Granary Bins, Coal Bunkers, Cement Stores, Walls, etc., of Expanded Steel and Concrete.

METHOD OF CONSTRUCTION.

THE object attained by the method of construction described below is that the outer and the inner division walls forming the bins are constructed of concrete, having continuous layers of Expanded Steel embedded within both sides thereof, in continuous and connected sheets—the Expanded Steel thus forming a tension bond to resist pressure from either side, as the adjacent bins may be full or empty. The concrete walls decrease gradually towards the top, their thickness at the top being about half that at the bottom.

For rapidity in construction and to ensure the steel work all being in its proper position before the concrete is imposed, and to avoid the possibility of any cross section stratification in the concrete, it is advisable that the walls, interior and exterior, of the whole area of the granary should be built up simultaneously in equal courses. The height of these courses is governed by the height of the cribbing or centering which is used to form them.

The centering is composed of a collapsible and extensible wood framing and boarding of size and shape to provide the necessary conformation of the walls and columns at the intersections of the walls. The foundations of the building being ready to receive the super-structure, these collapsible wood centerings are disposed over the whole area of the building, as many of them being employed as there are bins to be formed, and are set in position in respect to the plan of the granary, as shewn. In the first instance, two courses of centering are placed in position, one on top of the other, so that when the bottom course is struck, the second course will remain in position to receive the next.



— Sectional Plan. —

EXPANDED METAL AND CONCRETE
as applied in the construction of
GRAIN SILOS ETC.

The first course of centering is raised one inch from the foundation by means of removable blocks or wedges of wood, so that after the first and second courses of concrete are built in, this first section of the collapsible centering will have a clearance beneath it, which arrangement affords the necessary facility for striking. As soon as the two courses of the centerings for the interior of the bins are set in position, sheets of Expanded Steel in lengths slightly exceeding the length of one side of the bin, the long way of the mesh, by six feet short way of mesh in height, are placed between and against each face of the centerings, and supported in such position by means of dogs (described later), and strips of wood of the proper width to separate the sheets, and to permit of the concrete being imposed between the steel sheets. These separating strips are also used for ramming the concrete and are operated in and above the concrete by hand as the work proceeds. As they are of less width than the space between the centerings and that taken up by the metal, the fine material of the concrete passes to the back of the metal and creates a smooth facing embedding the Expanded Steel.

The hoarding for the outer walls is composed of longitudinal timbers and vertical planking. The longitudinal pieces, after the first course, are anchored to the cross wall by means of an iron rod secured to an iron plate or cross-tail at its inner end, and having a threaded outer end, which passes through the waling pieces and is provided with a nut to hold the latter in position, to receive the vertical planking.

The walls having been built to a height of say five feet nine inches, three inches of the Expanded Steel sheet thus being left exposed, and the concrete in the first constructed bins having set sufficiently hard to permit of the removal of the first section of centering, the latter is removed or collapsed inwardly and lifted in four sections and again set in position on the top of the second series of centering; and when all are thus set sheets of Expanded Steel of the same length as before, but three feet three inches in height are placed in the same way as previously described, their lower edges resting on the concrete and overlapping the lower sheets three inches.

The concrete is then imposed between the centering, and through the meshes of the metal, as before described.

The walls now having risen to a height of nine feet, it is desirable to have a more convenient means of lifting the centering than by hand. A scaffold pole is, therefore, set at the centre of each bin, a platform provided around it and made to travel level by means of a central drum, and is lifted by means of a rope and tackle to a sufficient height to receive the collapsible centering, which is then raised six feet, and slightly above the level of the last course of centering, and is set thereon as before described. After two or three courses of centering have been removed, the scaffold pole is strutted to the concrete walls by horizontal cross-timbers, spiked to the scaffold pole. This strutting can be done at frequent intervals as required.

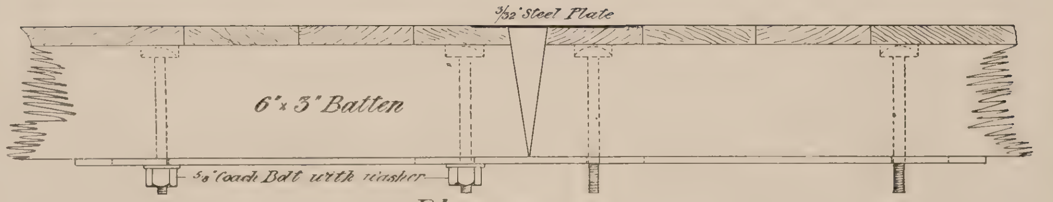
In all subsequent elevations the height of the Expanded Steel sheets would be three feet three inches and the concrete filled in to within three inches of the level of the tops of the last course of centerings, until the final course is reached.

The vertical sheets of Expanded Steel are connected one to the other through the concrete by means of dogs made of $\frac{1}{4}$-inch round iron, set 18 inches apart in either direction, and hooked through the meshes of the metal.

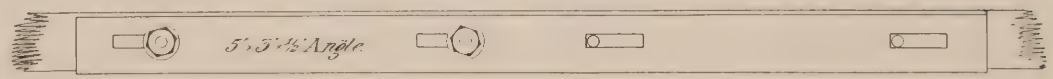
The walls of the building are further bonded together by means of strips of Expanded Steel, four feet in length by five inches in width, laid flatwise at the intersections of the walls, and crossing the columns in each direction. One of these strips is so laid when the first one foot of concrete is filled in, and another strip is so laid in the opposite direction when the next one foot of concrete is placed—and so on at each corner as each one foot of concrete is completed throughout the height of the walls, until within three inches of the top of the walls, at which point cross strips are introduced, one in each direction, prior to filling in the final three inches of concrete, which is floated smooth and level, or as may be desired.

The sheets of Expanded Steel which are set vertically in the walls are of three inch mesh.

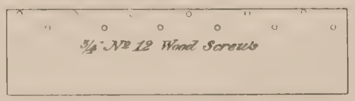
The strips of Expanded Steel laid flatwise bonding the walls through the columns are of $1\frac{1}{2}$ inch mesh.



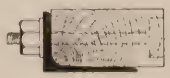
—Plan.—



—Elevation.—



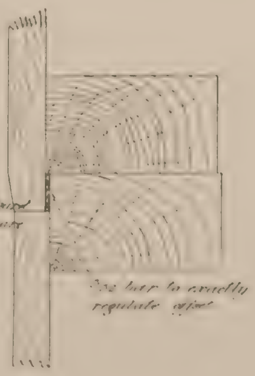
—Plan of Steel Plate.—

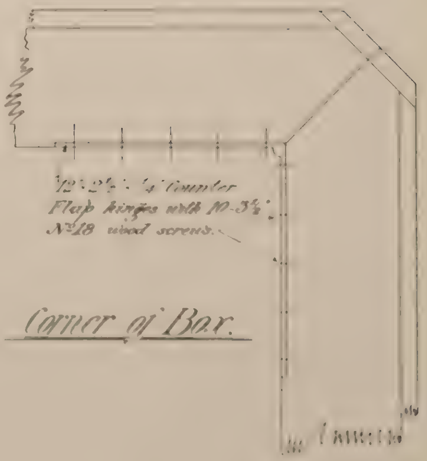


Note. Angle reversed on bottom batten

—End of Angle.—

—Apparatus for enlarging Boxes.—

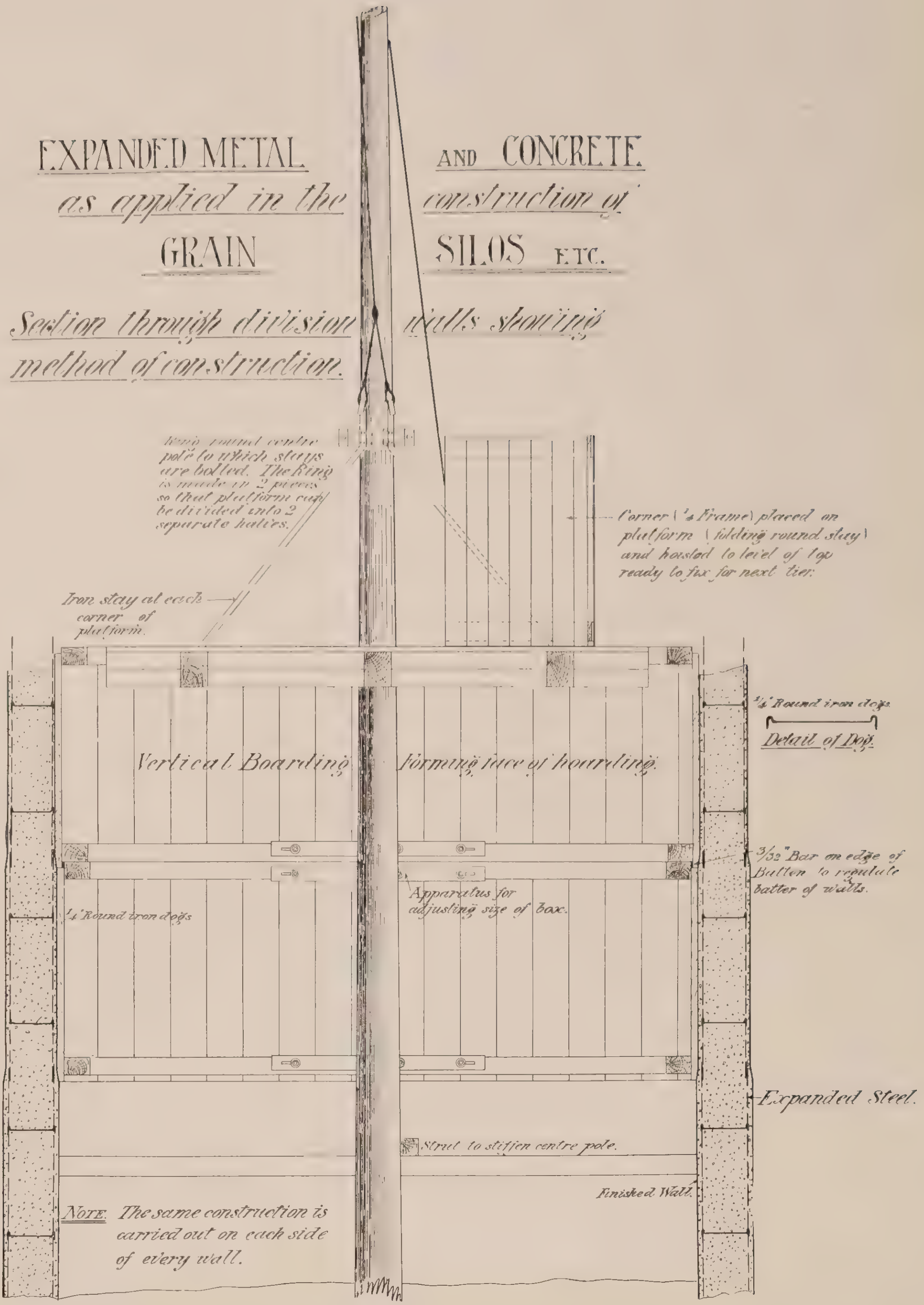

Bevelled Board to avoid square edge
Use here to exactly regulate edge


12" × 2 1/2" × 1/4" Counter Flap hinges with 10-3/4" No 18 wood screws.

Corner of Box.

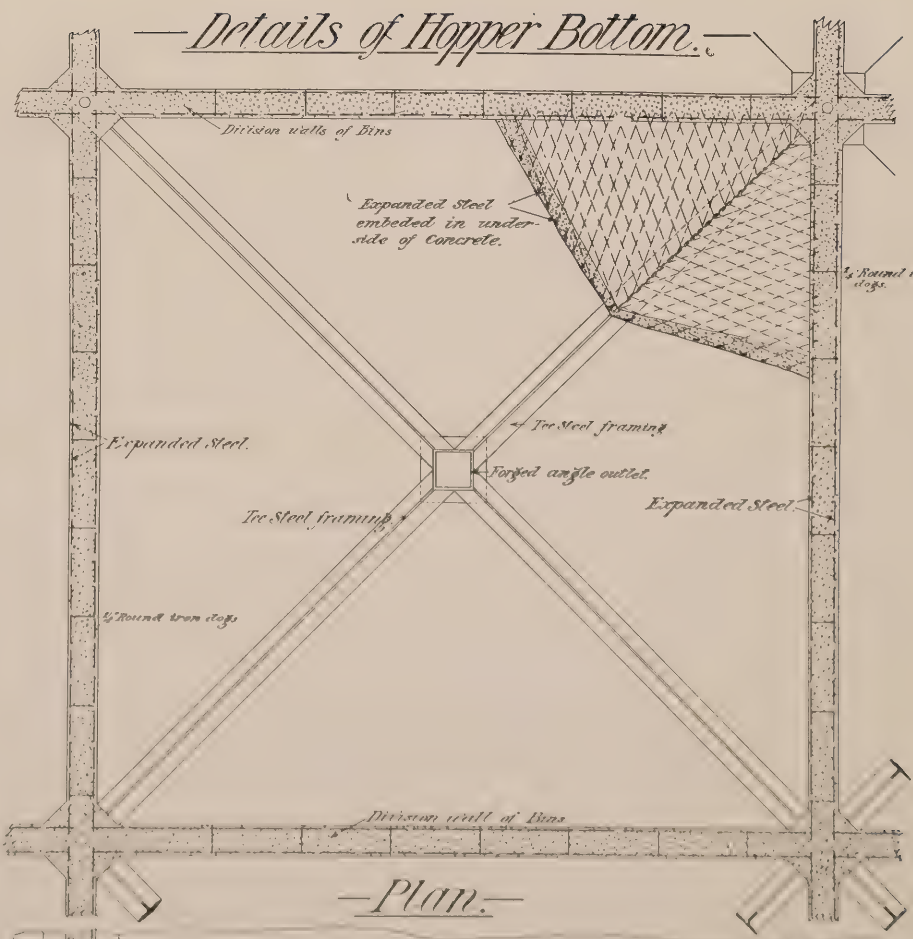
EXPANDED METAL AND CONCRETE as applied in the construction of GRAIN SILOS ETC.

Section through division walls showing method of construction.

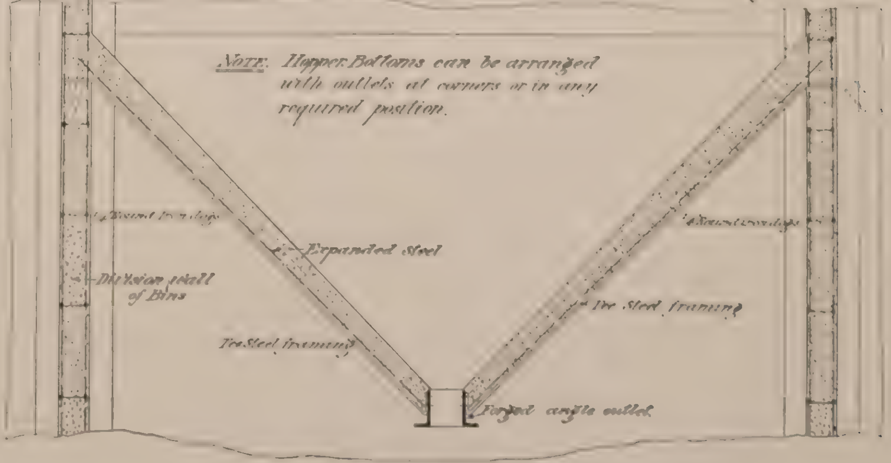

Ring round centre pole to which stays are bolted. The Ring is made in 2 pieces so that platform can be divided into 2 separate halves.
Corner (¼ Frame) placed on platform (folding round stay) and hoisted to level of top ready to fix for next tier.
Iron stay at each corner of platform.
¼" Round iron dogs.
Detail of Dog.
Vertical Boarding
forming face of hoarding.
3/32" Bar on edge of Batten to regulate batter of walls.
¼" Round iron dogs
Apparatus for adjusting size of box.
Expanded Steel.
Strut to stiffen centre pole.
Finished Wall.

NOTE. The same construction is carried out on each side of every wall.

—Details of Hopper Bottom.—



—Plan.—



NOTE: Hopper Bottoms can be arranged with outlets at corners or in any required position.

—Section.—

Steel-Armoured Concrete in Bridges.

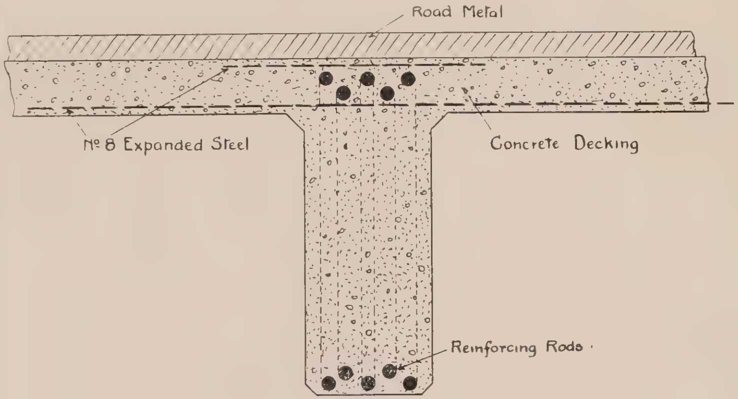
THE combination of steel and concrete for the erection of bridges is one of the most general uses to which these materials have been put in their combined form. A great many engineers throughout the country have designed concrete steel bridges, and strong claims are made for the various plans. In the ancient days concrete was used alone for bridge construction, and many arch bridges of this material are still in use, although thousands of years old.

For the past twenty-five years steel alone has been the ruling material for bridge construction, and large combinations of capital are carrying on the business constantly. However, the greatest economy has been effected by combining steel and concrete. By this combination not only is economy in cost secured, but much more effective results can be gained, besides a much longer guaranteed life.

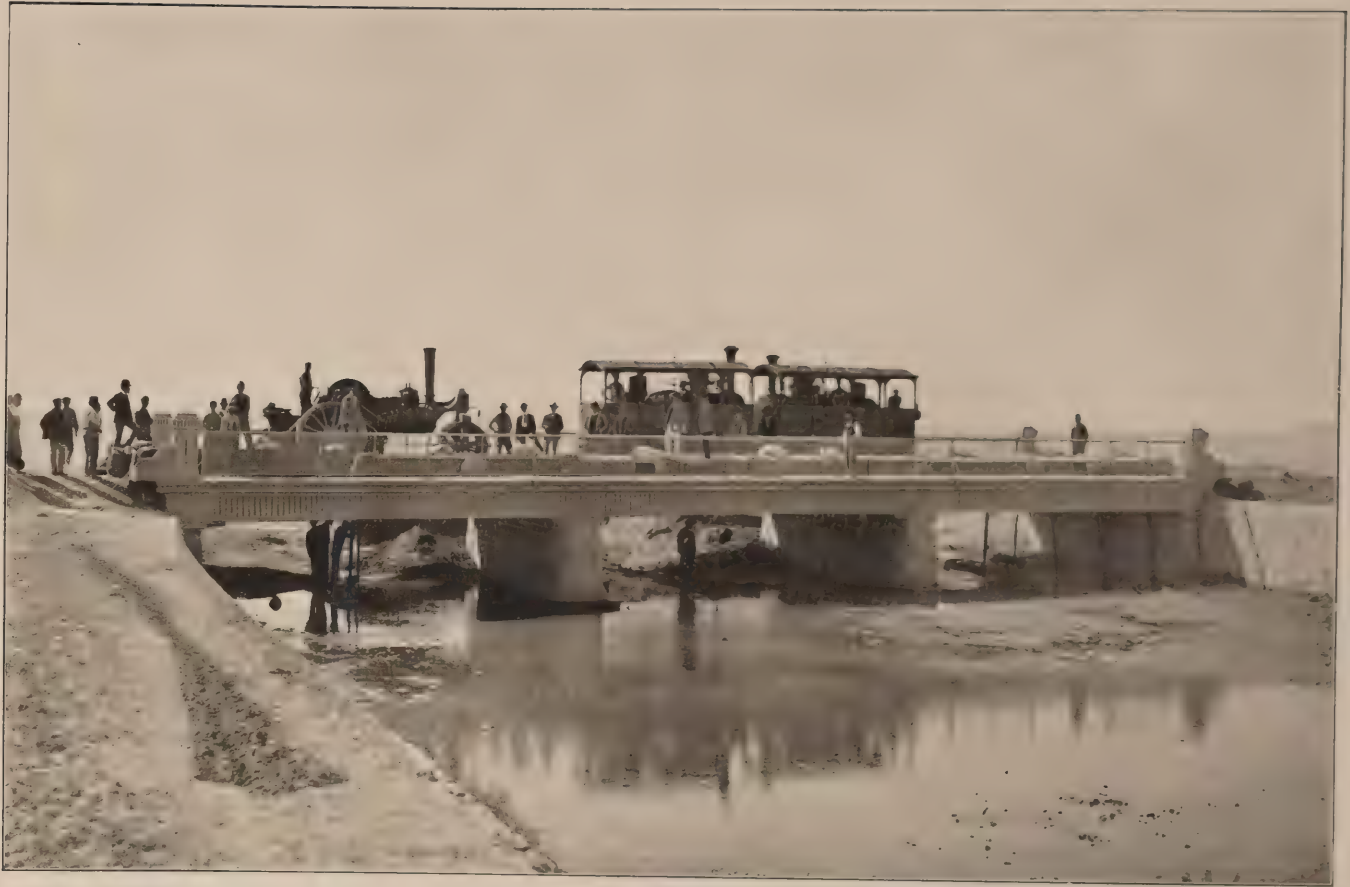
The efficiency of Expanded Steel for the steel member of this combination has been proved in many ways. We show only a few illustrations representing instances where Expanded Steel-Armoured Concrete has been used for the purpose in question.

With regard to the beams, where steel is cheaper and readily obtained, there is no doubt that built up girders are cheaper than beams of rods and concrete on account of the heavy cost of temporary centering required for the latter, but in Greece, for example, it has been proved that the armoured concrete bridge is decidedly the cheaper construction, and we give an illustration of one on this system, viz., Pont Ilyssos, Piræus, Greece, constructed by M. Constantin G. Basiliades, a local engineer, and our representative for Greece. The bridge is 90 feet long, constructed in three equal spans resting upon concrete caissons. The width of the structure is 26 feet. The beams supporting the decking are at about 5 feet centers and are constructed of round rods and concrete. The decking and side walks are of Expanded Steel and Concrete, the former our No. 8 3-inch mesh $\frac{1}{4}$-inches by $\frac{1}{8}$-inch strand and the latter $4\frac{1}{2}$-inches in thickness. The parapet fencing is of Expanded Steel framed up in panels and having a suitable coping, fixed to standards at adequate intervals. The bridge when completed was subjected to a very severe test by the Government engineers, and our illustration shows this test satisfactorily completed.

Many girder bridges have been built in this country with Expanded Steel and concrete decking and as our works have now laid down machinery to expand steel sheets up to 16ft. the long way of the mesh, spans up to this dimension can be readily dealt with on our system, which undoubtedly offers many advantages over the old R. S. J. and concrete system.



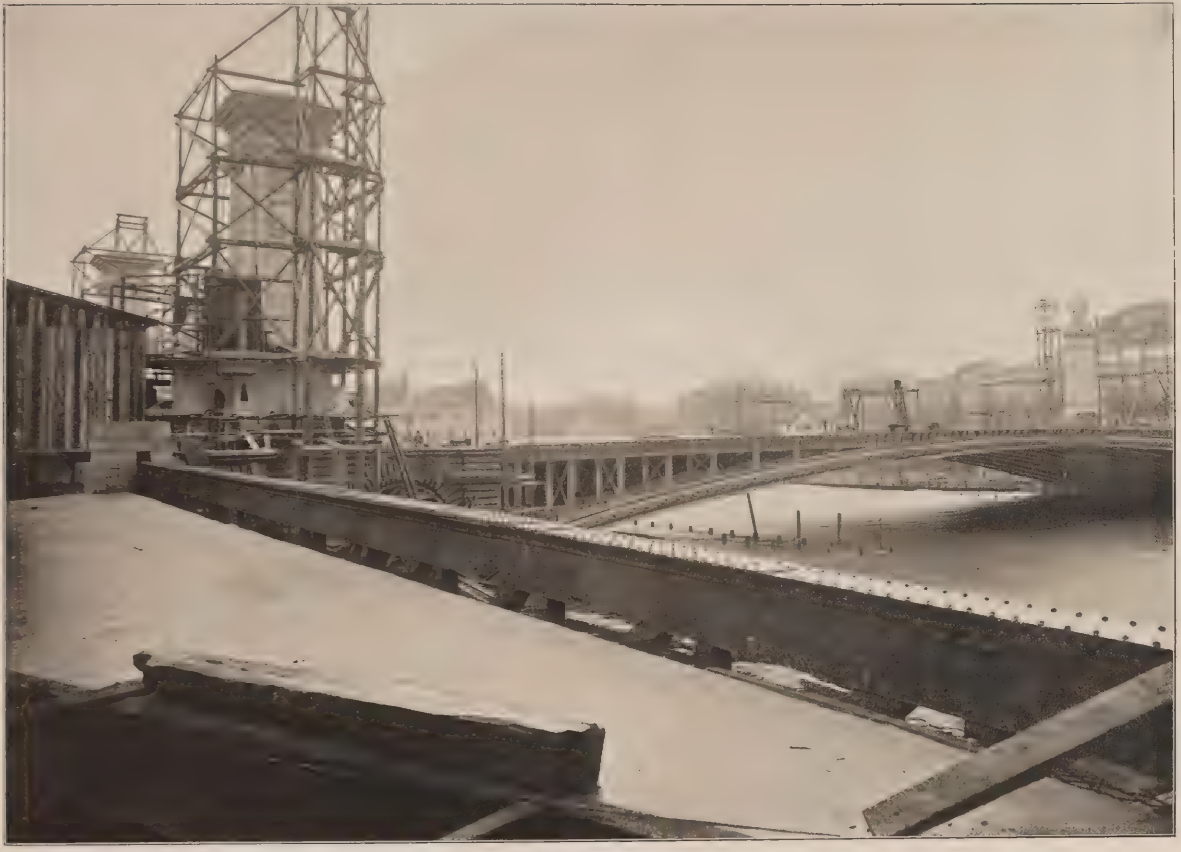
SECTION THROUGH BEAM.



BRIDGE OVER ILYSSOS, PIRÆUS, GREECE.

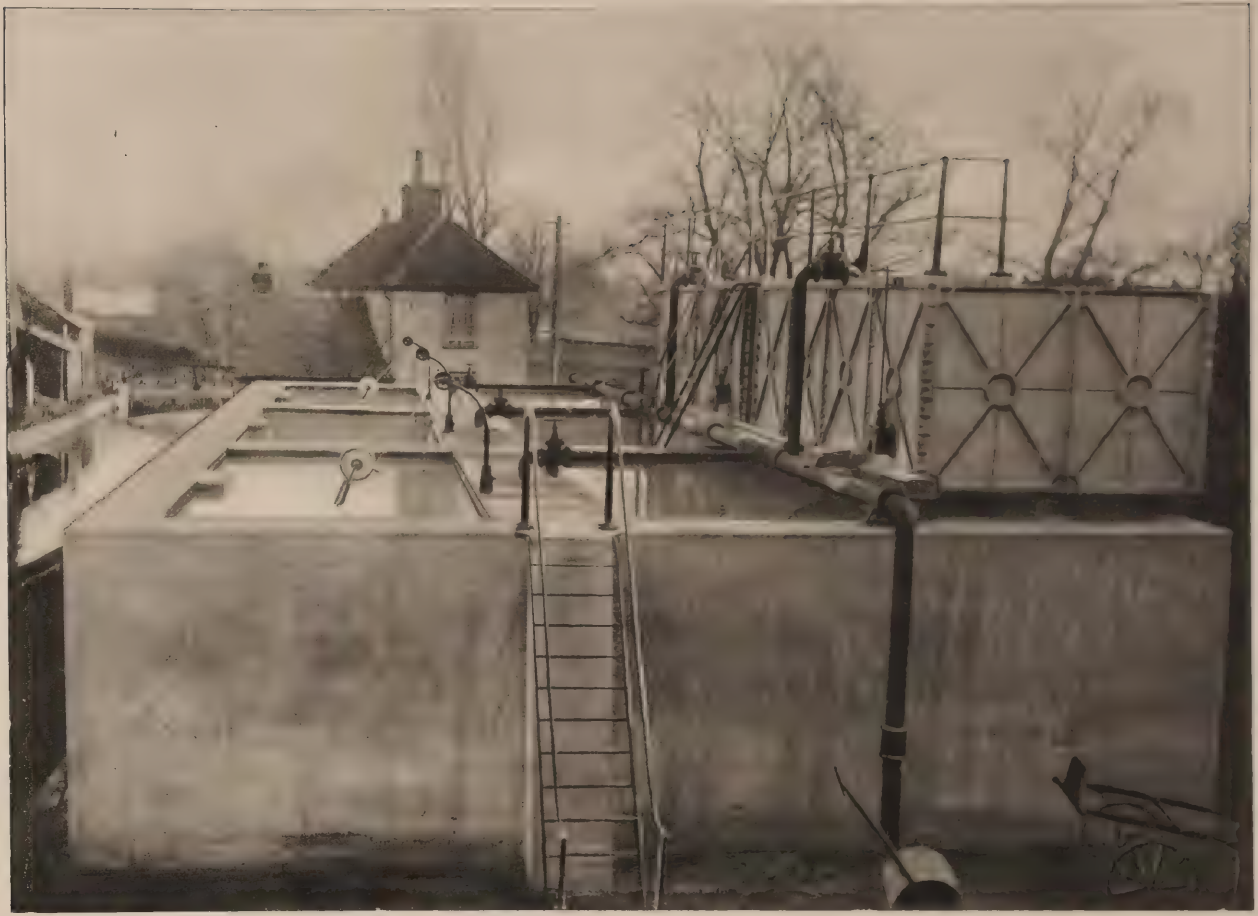
Rods and Concrete Beams and Expanded Steel and Concrete Decking.

M. C. G. BASILIADES, Engineer.



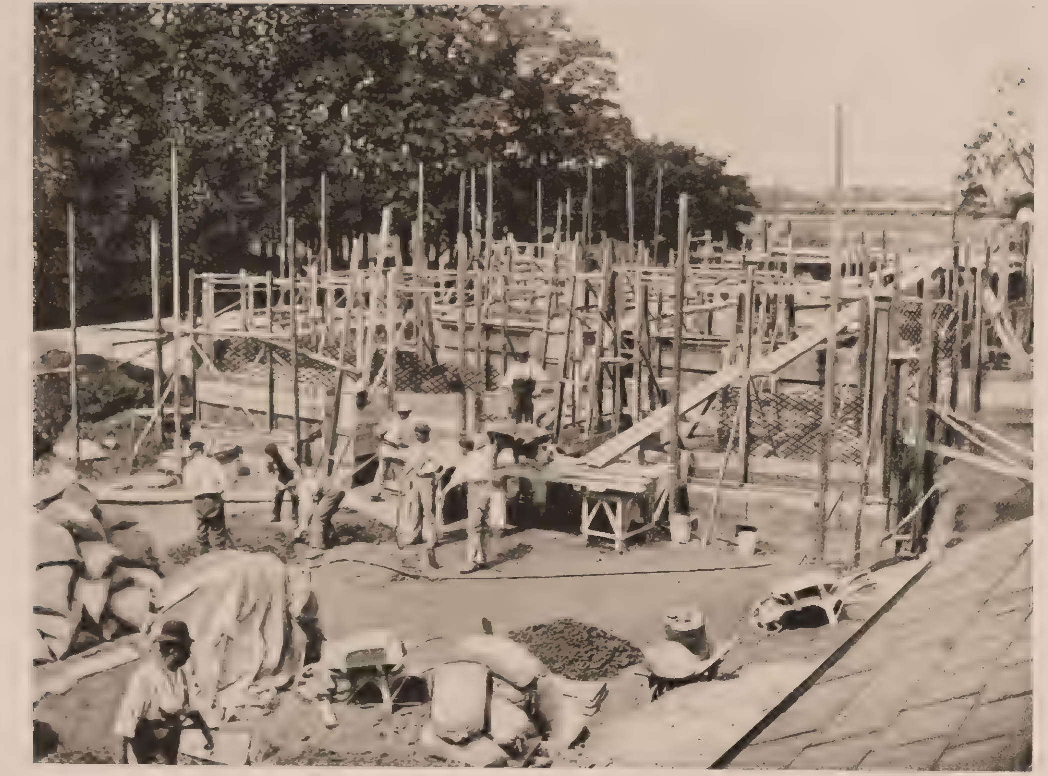
PONT ALEXANDRE III, RIVER SEINE, PARIS.

Expanded Steel and Concrete Decking.



EXPANDED STEEL AND CONCRETE WATER SOFTENING TANKS.—Messrs. S. Courtauld & Co., Ltd., Works, near Braintree

Mr. J. CLAYTON, M.I.M.E., Engineer.



Expanded Steel and Concrete Sewage Tanks in course of construction at Messrs. Saml. Courtauld & Co.'s, Ltd.. Works, Bocking, near Braintree.

Mr. JAMES CLAYTON, M.I.M.E., Engineer.

Sewage Tanks.

SOME time ago we were asked to call upon Messrs. Courtauld and Co., of Bocking, near Braintree, the famous Crape Weavers, with regard to some Sewage Works they proposed to construct. The following letter from their engineer, Mr. James Clayton, M.I.M.E., explains the work in detail:—

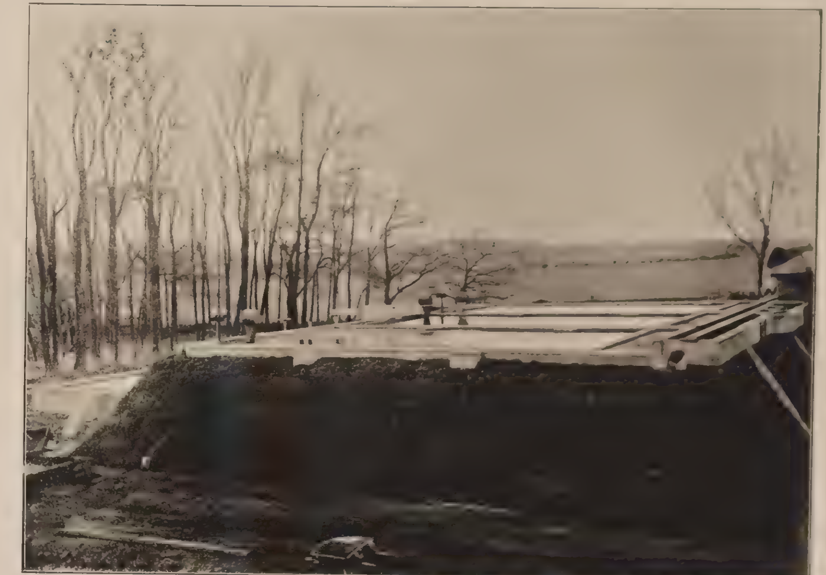
"*4th Sept.*, 1901.

"DEAR SIRS,

"Replying to yours of the 2nd *re* my experience of the Expanded Metal in the construction of our Sewage Works. As you know, my reason for using the Metal was simply and solely on account of the soft nature of the foundation. Upon excavating, we found that the ground consisted of about 4 feet of good bearing clay, under which was 6 feet of soft peat; then came the gravel.

"It was impossible to go down to the gravel to secure a good foundation, owing to the vast amount of water met with. To pile the whole of the foundation was too expensive to consider. I therefore decided to simply level the site, and to put the concrete tanks upon the clay; at the same time, as I expected considerable settlement (and probably uneven settlement, owing to the varying nature of the ground), I freely used the Metal in the construction of the walls, to bind the whole fabric together, and so compel it to settle without rupture.

"In order to gauge the amount of settlement I took levels, and found that, even before the water was put into the Tanks, they commenced to settle at one end. In four weeks the settlement was 1¼ inches, and it then stopped. When the water was run into the Tanks, thus increasing the weight by 600 tons, the settlement was very rapid, the amount being 1¾ inches in two weeks. The settlement at this period stopped, and the Tanks are now 3 inches out of level.



Expanded Steel and Concrete Sewage Tanks completed and in use at Messrs. Saml. Courtauld & Co.'s, Ltd., Works, Bocking, near Braintree.

Mr. JAMES CLAYTON, M.I.M.E., Engineer.

"I was very much concerned, as you may imagine, during the settling, as the amount was considerably more than I had anticipated, but I am happy to say that the Works have been running four months and no cracks have appeared as yet. There is not the slightest doubt that the Expanded Metal assisted in keeping the mass together, and without it, the job would have been a failure.

"The Metal was very easy to fix, but we had to cut the 8 feet by 8 feet sheets in two, to avoid having to lift the concrete so high.

"The works cost £[illegible], and are in every way a success.

"If you care, I shall be pleased to show you or any of your clients the works.

"Yours faithfully,

(*Signed*)

"JAMES CLAYTON,
M.I.M.E."

And under date 3rd November, 1902, we received a letter from Mr. Clayton, saying: "the Works have been in successful operation ever since they were completed, and so far no cracks have appeared in the walls."

We give an Illustration of the Works in progress.

Ammonia Tanks.

AT the local gas works of Racine, Wis., there have been built two large tanks or wells of concrete reinforced with Expanded Steel. These tanks are for the storage of tar and ammonia extracted from the coal in the process of manufacture of gas. They are each 25 feet in diameter and 9 feet deep. The exterior walls are 17 inches thick at the top, tapering to somewhat larger dimensions at the bottom. The footings of these walls were 12 inches in thickness, which footing rested on gravel foundations. The tanks are each covered with a concrete slab containing Expanded Steel, and resting upon I-beams bearing upon the outer walls. The Expanded Steel in the walls was placed close to the outer side The resistance calculated was 500 pounds per square foot. The concrete used was one part cement, two parts sand, and five parts of broken stone. The tanks have been in use for several months, and have answered every requirement without damage or harm.

Some two years ago the engineer of the Kendal Corporation Gas and Electricity Works was desirous of turning a small reservoir into an Ammonia Tank, by placing a cover over the reservoir. The Tank was about 37 feet in diameter.

We submitted a scheme and price, which was accepted, and constructed the cover as follows :—

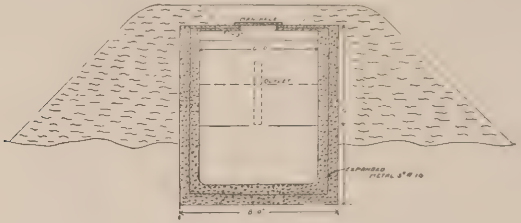
Two concrete piers were built, and a rolled steel joist thrown from wall to wall on the centre line of the tank, resting on the piers. Pockets were cut out of the existing concrete walls, and pieces of 3-inch by 3-inch angle steel 7 inches long inserted to receive the cambered steel channels, which, being filled with concrete, formed secondary ribs, in place of ordinary R.S.J.'s. Temporary wood centering was erected, and an Expanded Steel and Concrete cover constructed. The cover was laid to fall, and finished with asphalte.

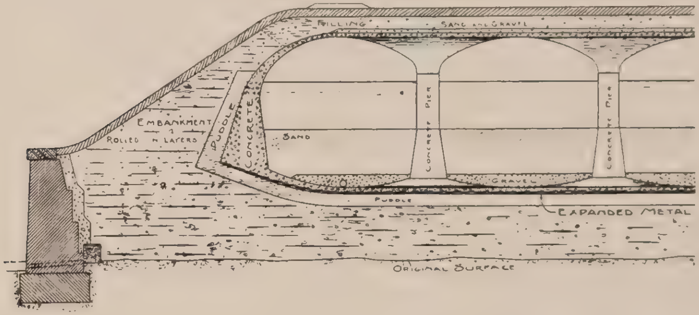
The temporary wooden centering was struck in due course, and the whole of the steel work encased with Expanded Steel lathing and cement plaster. The Tank is now full, and giving every satisfaction.

In another instance, that of a small reservoir at the St. Mary Cray Gas Works, the engineer desired to destroy an existing cover, and construct a new one. The Tank was full of tar and could not be emptied, therefore some slight difficulty presented itself. We submitted a scheme and price, suggesting that the temporary centering be left in, thus obviating the necessity of emptying the Tank. Our offer was accepted, and the cover is giving every satisfaction.

Septic Tanks.

THE accompanying illustration is a cross section of a septic tank. The tank in question is 30 feet long and 9 feet deep by 6 feet wide. The walls of the tank are 12 inches thick, being reinforced with a layer of No. 10 3-inch mesh, $\frac{1}{4}$-inch by $\frac{3}{16}$-inch strand Expanded Steel around the sides and top. It was built upon practically level ground, and afterwards an earthen embankment built around it.



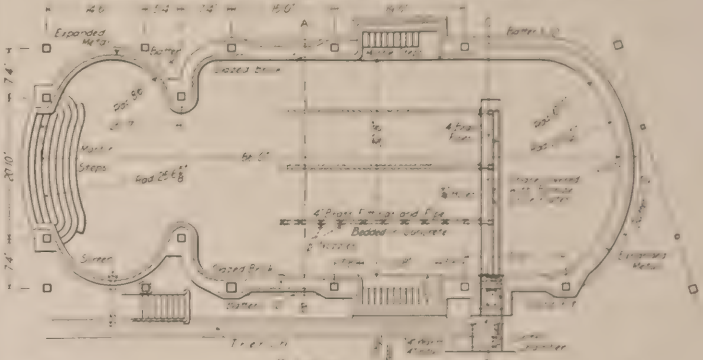


The above section shows an interesting example of Filtration Reservoir construction. In this particular work the filtration beds are built upon "made" ground, and the Expanded Steel is used to prevent the cracking of the concrete bottom. In this work a quantity of over 1,000,000 square feet of No. 10 3-inch mesh $\frac{1}{4}$-inch by $\frac{3}{16}$-inch strand Expanded Steel was used.

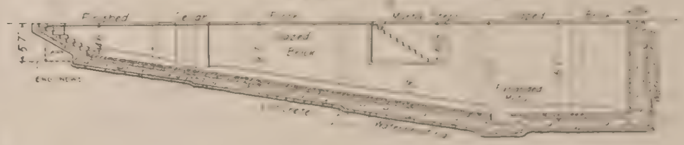
A Swimming Tank.

WE extract the following from a description recently published in the "Engineering News" and are under obligation to them for the following illustrations.

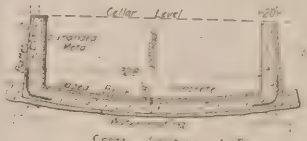
> "In the construction and equipment of the large 16-story apartment house situated "at 74th street, and Broadway, in New York City, there was built in the basement the "swimming tank of concrete steel construction, details of which are shown in the "accompanying illustrations. The drawings show the construction so clearly that but very "little description is required. As will be seen, the metal element of the tank is expanded "metal; all other portions of the structure are of concrete, except of course, the glazed "brick lining, marble steps, iron railing, &c. In plan the tank is unusual, owing to the "necessity of getting it between the building columns. This building, to be known as the "'Ansonia,' is owned by W. E. D. Stokes, Esq., and the architect is Paul E. Du Boy."



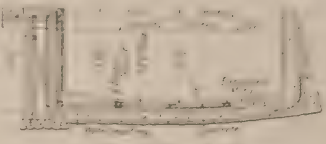
Plan



Longitudinal Section



Cross Section A-B

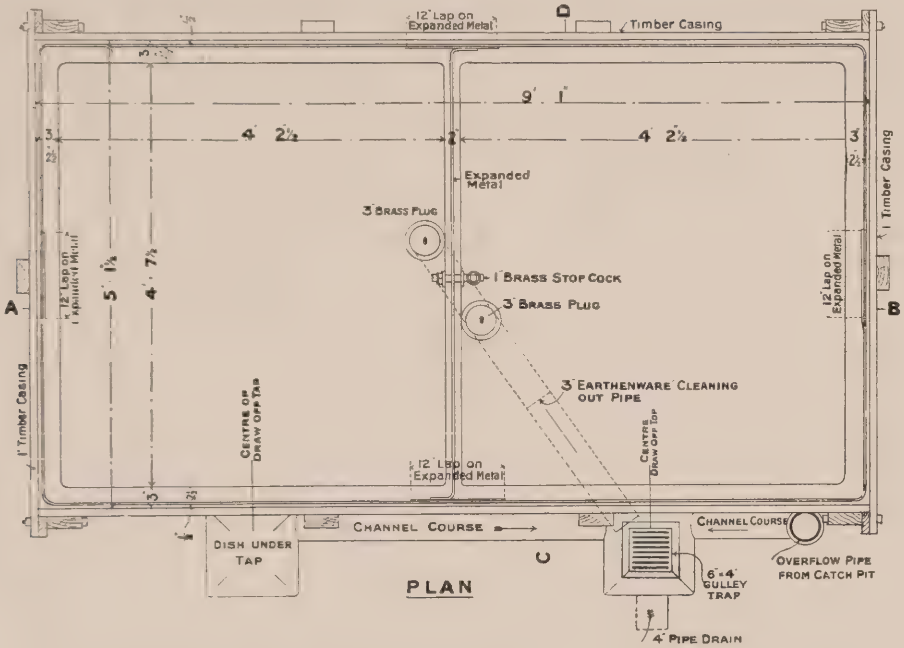


Cross Section C-D

Water Tanks.

THE two illustrations here shown are of Expanded Steel and Concrete Water Tanks constructed for the Irish Lights Office at various stations under their supervision, a list of a few of which places we also give. The details on the sketches will fully explain the system.

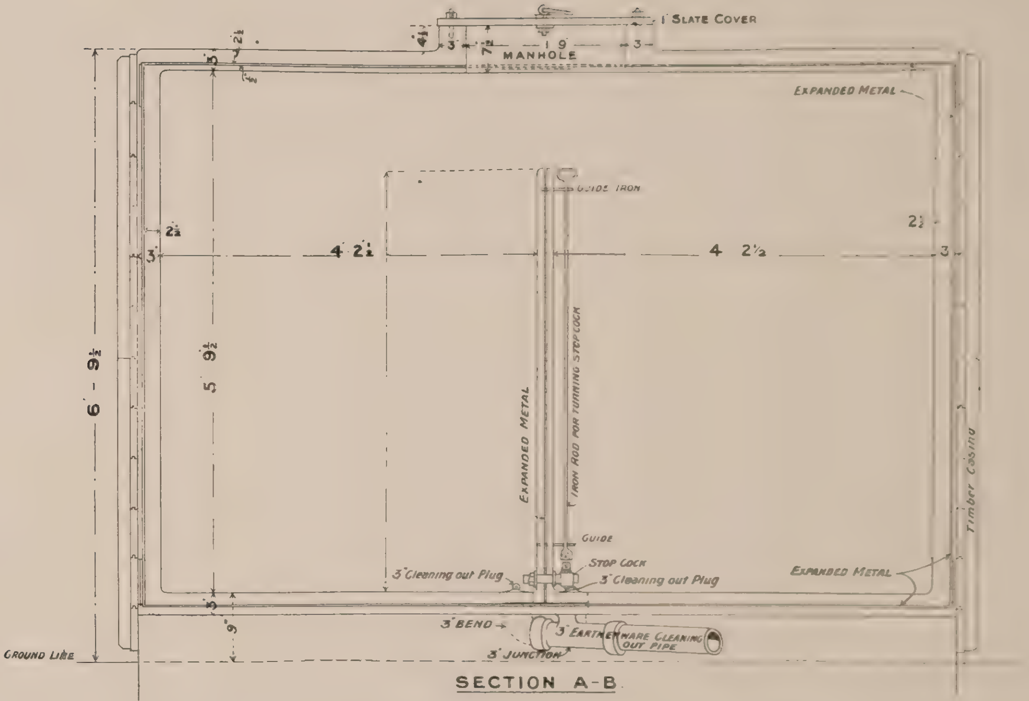
Hook Tower,	Co. Waterford.
Quishgort,	Co. Mayo.
Duncannon Fort,	Co. Wexford.
Kinsale,	Co. Cork.



Expanded Steel and Concrete Water Tanks at various stations for The Commissioners of Irish Lights.

Poer Head,	Co. Cork.
Wicklow Head,	Wicklow.
Loop Head,	Co. Clare.
Coran Island,	South Co. Galway.

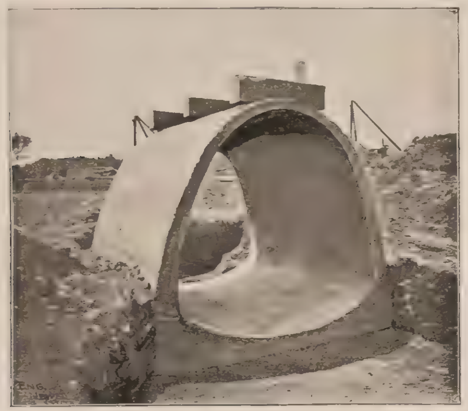
The Engineer to the Irish Lights Office has expressed his entire satisfaction with the tanks, no matter how exposed the position which the tanks occupy.

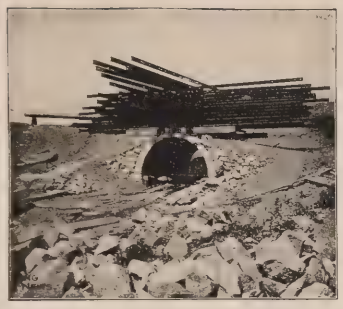


Expanded Steel and Concrete Water Tanks at various stations for The Commissioners of Irish Lights.

Water Conduits.

IN the securing of a new permanent water supply for Jersey City, U.S.A., from a large storage reservoir erected at Boonton, N.J., it became necessary to convey the water through many miles of conduits, tunnels and steel pipe. For the conduit section it was originally intended to use brick arches; this was afterwards modified to a concrete arch, and later, changed to a combination of concrete and Expanded Steel. As originally designed by Mr. E. W. Harrison, Consulting Engineer of the Jersey City Water Supply Company, the conduit was intended to be constructed 12 inches at its top or smaller dimension. There was erected in May, 1900, a test section of the combined Expanded Steel type, the section being 10 feet in length. As compared with the "all concrete" section, it contained 1 cubic yard per lineal foot of pipe section as compared with 2 cubic yards for the original. The new section was reinforced with Expanded Steel in the manner indicated in the figure accompanying this article.

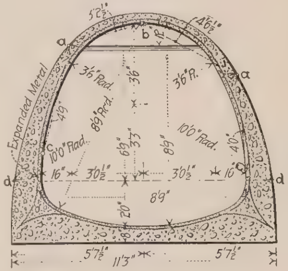




The design, as shown, is practically an ellipse with the haunches and bottom forming an inverted arch. The material used was crushed stone $1\frac{1}{2}$ inches, 1-inch screenings and sharp pit sand, and the mass was in proportions of one of cement, two of sand and five of broken stone. Thirty days after building, the section in question was tested under supervision of the Company's engineers.

Three saddles of timber had been set on the crown of the arch, shown in Fig. 2, one in the centre and one at each end, and one layer of nine rails had been laid on these saddles. The actual test began at 2.45 p.m., laying rails on, one by one, while a level had been set up to determine any deflection. At 5.28 p.m., with a load of $21\frac{1}{2}$ tons, fine horizontal cracks began to show all along the extrado, but no measurable deflection took place.

When the loads had been increased to 25 tons, as shown in Fig. 2, three rails, weighing approximately 1 ton, were twice dropped on the rails on top of the arch over one end of the latter. The cracks were slightly widened and new fine cracks showed at the intrado and at the haunches, running all along inside the conduit section. When the rails were being dropped the level had been removed to avoid its being damaged.



The clear height of the section having been measured directly before the beginning of laying on rails, it was measured again 24 hours after completion of the test. The total deflection at the crown of the arch was $\frac{7}{16}$ths inches, and it had not increased under the constant load when again measured one month later.

As a result of the above test, the construction was approved, and contract let for this construction to the extent of about four miles.

Conduits and Filter Beds.

THE Application of Expanded Steel in the Conduits and Filter Beds at Torresdale, Philadelphia.

The Torresdale Filters which are now in the course of construction in Philadelphia, comprise the largest filter plant of the four being built by the City for the improvement of its water supply, and it is in fact the largest single plant in the world.

The filters are located on the Delaware River, below Torresdale, and the plant consists of fifty-five beds, each having an available filtering area of three-quarters of an acre, with a total filtering capacity of two hundred million gallons per twenty-four hours; a filtered water basin of fifty million gallons capacity and the necessary accessories.

In the construction of the plant it was found desirable to make use of reinforced concrete, and for this reinforcement Expanded Steel is being used. Several sizes are used, each being chosen to meet a particular requirement.

The floor of the filters consists of a series of inverted concrete arches, resting upon a twelve-inch layer of puddle, and carrying a series of concrete piers, at fifteen feet ten inches centers, supporting a concrete roof. The thickness of the concrete in the floor at the invert is six inches, and under the piers it is fourteen inches. Owing to the topography of the site it was necessary to build several of the beds on filled ground, and while these fills have been carefully made of selected material, well rolled in four inch layers, by a twelve ton steam roller, and furthermore given considerable time for settlement, it was thought advisable, to provide against possible local settlement, to reinforce the concrete floors of these beds with one

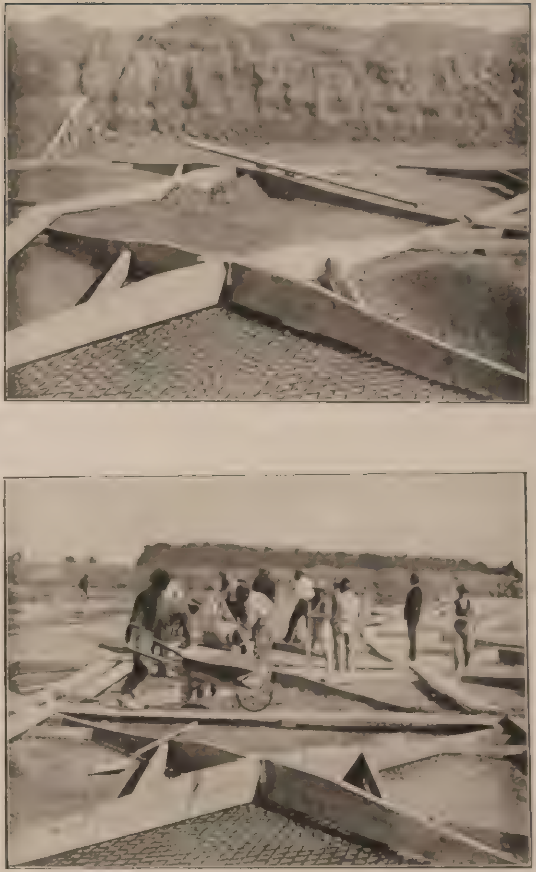


FIG. 1

layer of No. 10, three-inch mesh Expanded Steel placed one and one-half inches from the bottom of the concrete, each sheet lapping on the other not less than six inches.

Fig. 1 Shows the forms and the shape of the floor blocks, the Expanded Steel in place and concrete being deposited upon it.

Fig. 2 Shows the cross section of the main collector. This collector extends lengthwise through the center of each filter, and collects the filtered water from the underdrains and conveys it to the Regulating Chamber. The cover plates are concrete slabs reinforced with one layer of No. 10 three-inch mesh Expanded Steel as shown. In connection with the drainage system an 8-feet 6-inch concrete sewer, about 300 feet long, was built. In this sewer the concrete was reinforced with two layers of No. 10 three-inch mesh Expanded Steel as shown in *Figs.* 3 and 4.

The quantity of water to be filtered by this plant is so large that it was not economical to use cast-iron or steel pipes for the main conduits, particularly as it was necessary to have the least possible loss of head. It was therefore decided to build the conduits of concrete re-inforced by Expanded Steel.

The supply conduit which conducts the filtered water to the clear water basin is 2,200 feet long and is progressively 7 feet 6 inches; 9 feet and 10 feet in height.

The discharge conduit which conveys the water from the clear water basin to shaft No. 1 of the Torresdale Conduit is 850 feet long and 10 feet in height.

The by-pass conduit is 8 feet inside diameter and 800 feet long and connects the above two conduits and will be used, if it should be necessary for the clear water basin to be temporarily out of service. A section of the 10 foot conduit is shown in Fig. 5, the others, except the by-pass conduit, which is circular, are of the same general design.

All of these conduits will be under about 20 feet head and they are, we believe, the first large conduits built of concrete and Expanded Steel for conveying water under pressure.

The conduits are built in sections 12 to 13 feet long and as monoliths, a groove being left in the end of the section into which the next section is bonded.

Sufficient Expanded Steel is placed in the concrete to carry the tension stresses in the shell due to the water pressure.

This required either two layers of the standard 6 inch mesh or one layer cut double width with 6 inch mesh. The preference was given to the one layer of the heavier material. This size is being used on the discharge conduit but, owing to the difficulty of cutting, due to the lack of machines to cut such a wide section, it was necessary to use in the supply conduit two layers of the 6 inch mesh metal, the layers being wired together and put in as one. The metal is placed as shown and the lap between the different sheets and also at the end of the section is never less than 6 inches. The forms and centers in the 7 foot 6 inch and the 10 foot conduits are made of five and seven pieces respectively, so arranged that it is possible to take any one piece through a complete form that is set ahead of the center being struck.

The centers are allowed to remain in place about 60 hours after the concrete has been placed before striking.

The forms are covered with sheet iron which is cleaned and oiled each time before using. The sheet iron covering has proved to be very advantageous as it gives perfectly smooth work and protects the forms.

The progress made is about one section of each of the conduits, every other day, the rate is controlled entirely by the excavation. The trench for the discharge conduit is 34 feet deep and for the supply conduit 22 feet; the material is mostly sand and gravel, containing considerable water. The water is removed from the trench by a sub-drain, laid under and in advance of the conduit draining into a sump at one end or to one side of the trench.

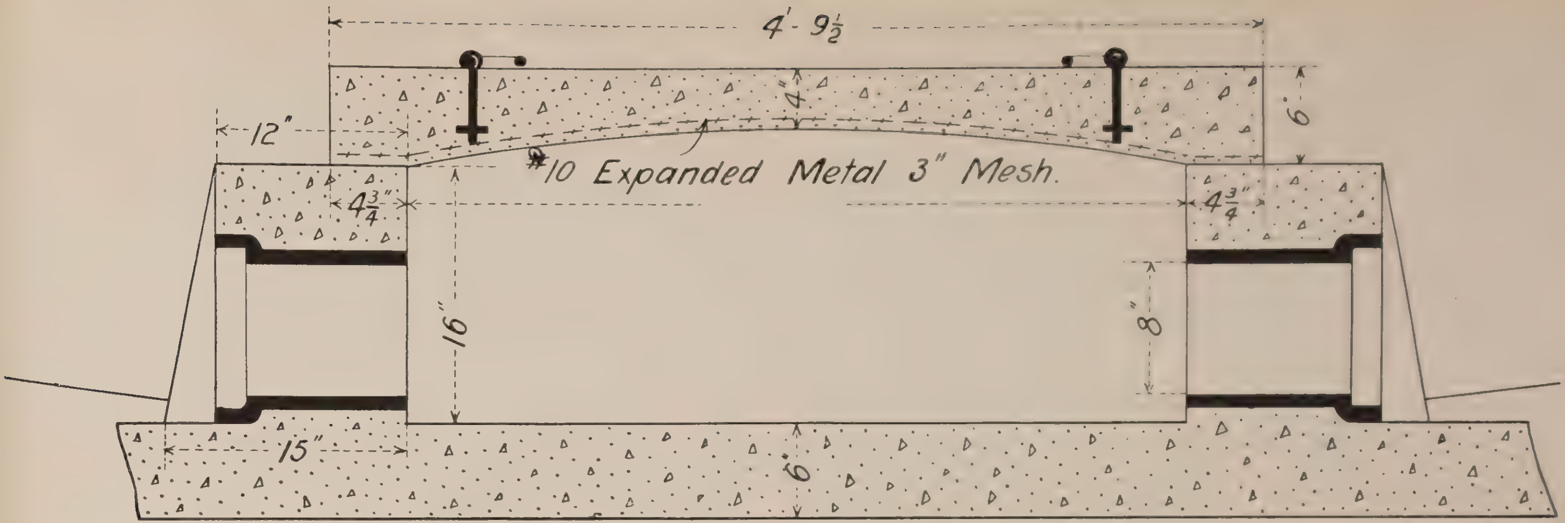


Fig. 2

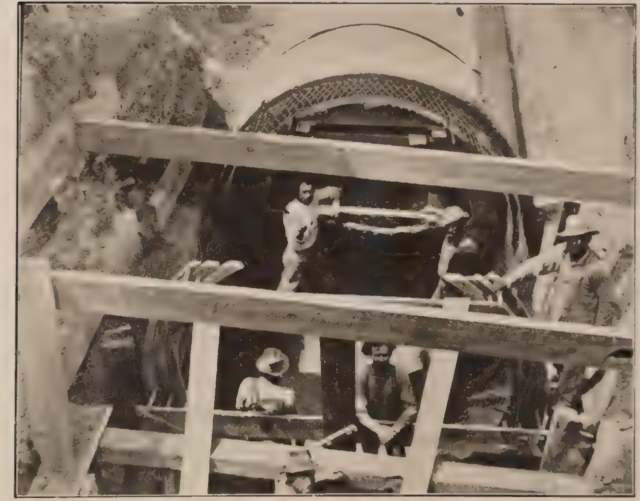


Fig. 3.

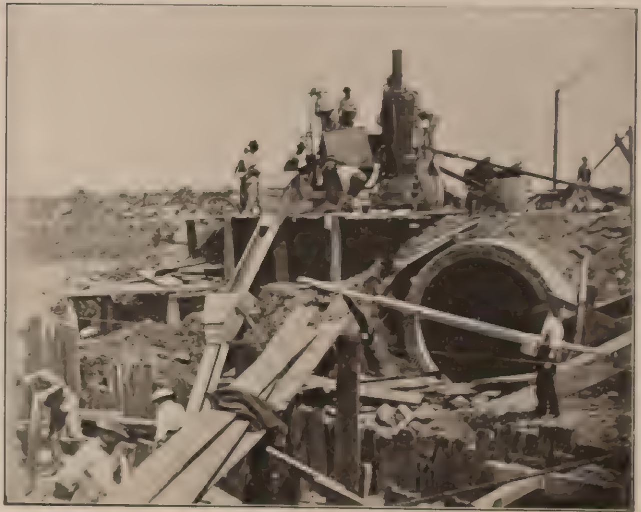


Fig. 4

The concrete is made in the proportions of one part Portland cement, three parts sand and five parts broken stone, the stone used is ¾-inch size.

The mixing for the discharge conduit is done in a portable cubical mixer of ⅓-cubic yard capacity and that for the supply conduit is done by hand, all being mixed very wet.

Against the face of the form is placed one inch of a granolithic mixture, made of one part Portland cement, one part sand, and one part granolithic grit. This mixture is made as thin as grout and is poured into the space between the forms and a metal sheet with lugs which leaves the thickness desired; this is done directly in advance of a layer of concrete, the metal sheets being drawn gradually during the ramming of the concrete. The workmen employed, other than the foreman and carpenters have been ordinary laborers and the work has been so smooth that no finishers were required. The cost of the work is low and the construction is good, two points which speak strongly in favour of reinforced concrete for similar types of work.

Mr. William C. Haddock, Director of the Department of Public Works, has general executive charge of the works for the improvement of the water supply; Mr. John W. Hill, Chief Engineer of the Bureau of Filtration, has direct engineering supervision of all the Work: Mr. Daniel J. McNichol is the Contractor for the Torresdale Filters.

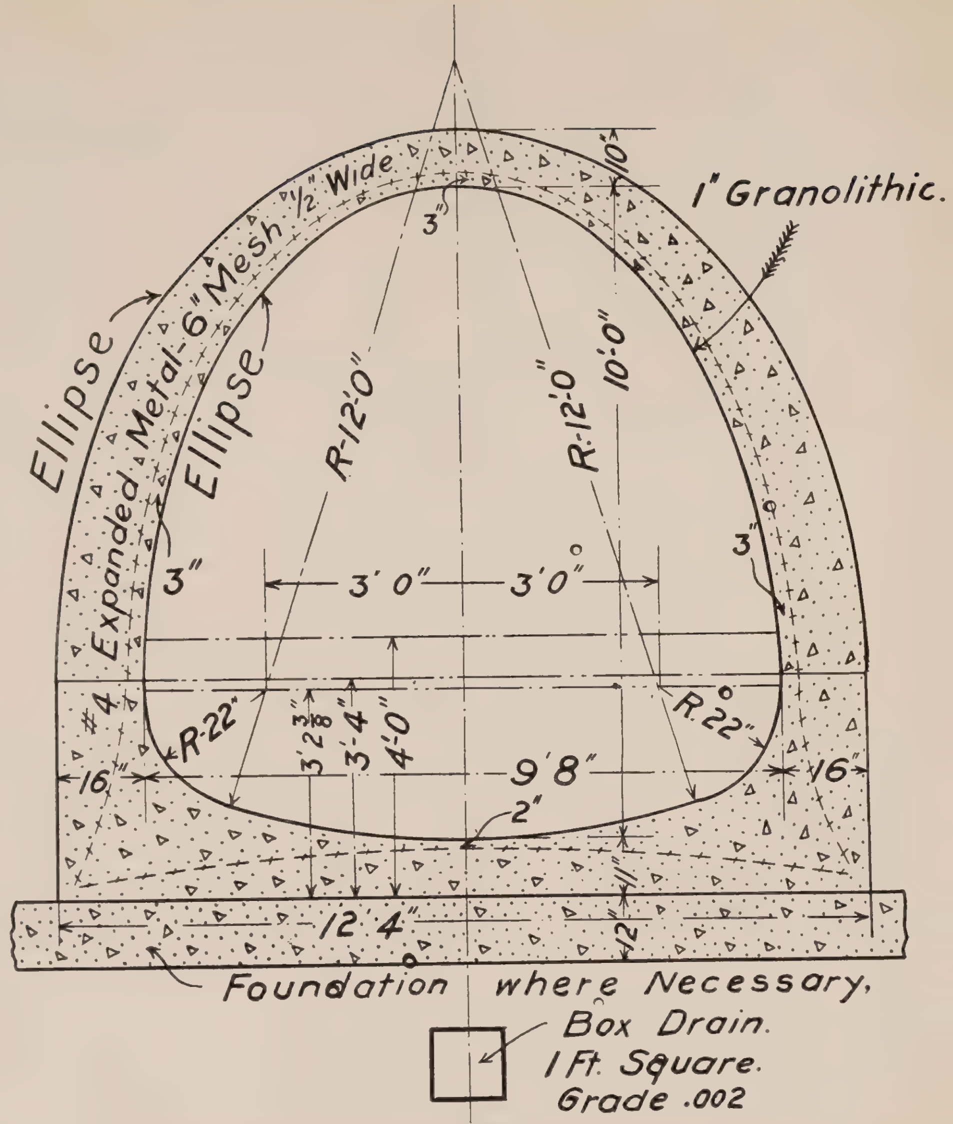
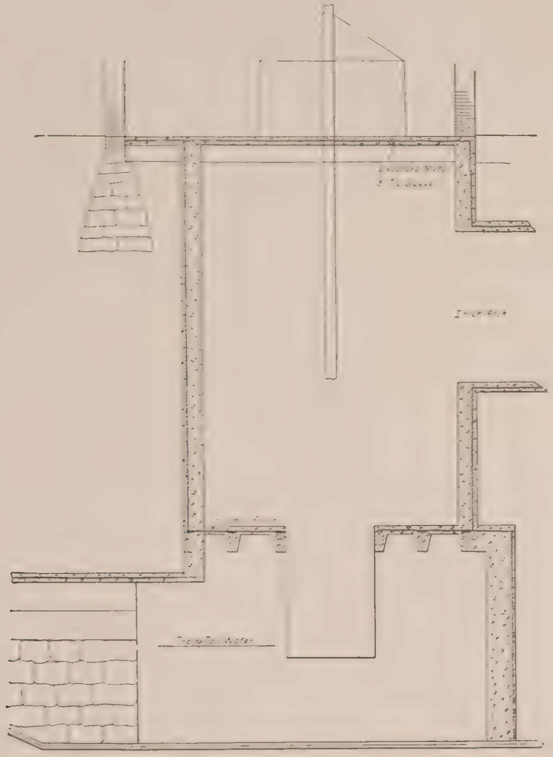


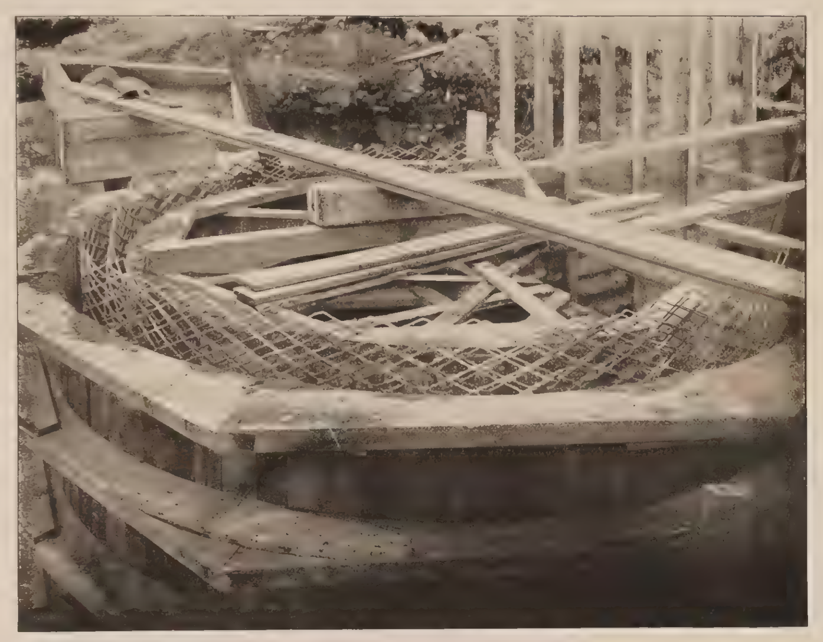
Fig. 5.

A Wheel Pit.

ONE of the most interesting combinations, from an engineering standpoint, which has been accomplished in Steel-Armoured Concrete construction is shown in the accompanying illustration, which is a wheel pit, including an inlet arch, flume floor, generator floors and tail race. The sectional illustration shows the general form of the work. The wheel pit is 13 feet in diameter, the inlet arch being 8 feet in diameter. The tail race is a comparatively shallow conduit 15 feet in width, and is covered by a segment arch formed of concrete and Expanded Steel.

In another illustration herewith we show reproduction of photograph of the wheel pit in course of construction.





The work was carried out with entire satisfaction and the same general scheme of construction is being adopted for other work of a similar character at the site of these works.

Extract from "FEILDEN'S MAGAZINE," December, 1902.

The Aberdeen Cable Subway and Outfall Sewer.

By G. R. G. Conway.

THE Town Council of the City of Aberdeen, during the Parliamentary Session of 1898-9, obtained powers for reconstructing the entire drainage system of the city. The new works, known as the Girdleness Outfall Scheme, were designed by Mr. Wm. Dyack, M. Inst. C.E., the burgh surveyor, and were favourably reported upon in 1898 by Mr. James Mansergh, F.R.S., past President of the Institution of Civil Engineers. The scheme involves the construction of large intercepting sewers and storm-water culverts, and it is expected that nearly £200,000 will be spent in their execution.

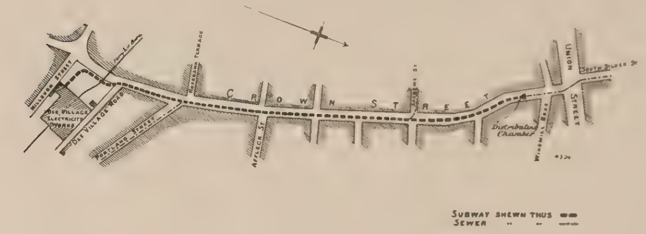


FIG. I.—PLAN SHOWING ROUTE OF SEWER.

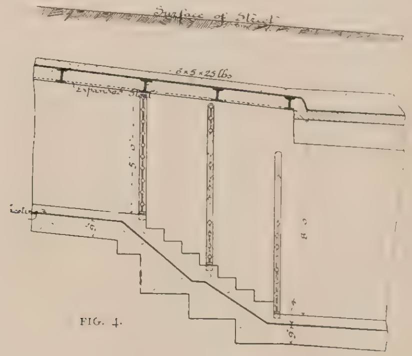


FIG. 4.

One of the most important sections of this scheme is the construction of a main outfall sewer, a little over three miles in length, at a cost of £75,000. This sewer intercepts the whole of the drainage of the western district of the city. Commencing at Skene Street, the sewer passes by way of Golden Square, South Silver Street, Crown Street, Portland Street, and the North Esplanade, to the south side of Aberdeen Harbour at Point Law. From this point the outfall will be tunnelled under the bed of the River Dee—the tunnel forming an inverted syphon—to the village of Torry, on the Kincardineshire side of the river; the outfall then passes under the high ground of Kirkhill, in a tunnel at one point 90 ft. below the surface, to the north foreshore of Nigg Bay, finally discharging its contents 22 ft. below high-water mark of ordinary spring tides at Girdleness, a rocky point south-east of the city. The outfall varies in size from 3 ft. to 7½ ft. internal diameter.

The works were begun in July, 1900, at Point Law, and were proceeding rapidly along Portland Street, when an arrangement was entered into between the Sewerage and the Gas and Electric Lighting Committees of the Town Council for modifying the outfall sewer in Crown Street, to admit of the construction of a cable subway on the top of the sewer, from Portland Street to Union Street—a distance of 600 lineal yards.

The electrical engineer's proposal to construct a subway was agreed to by the Town Council in November, 1900, and the burgh surveyor was authorised to prepare plans, and arrange a supplementary contract with the contractor for the outfall sewer works.

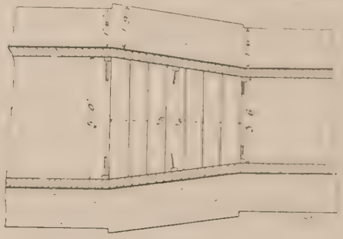


FIG. 5

The supplementary contract amounted to £8,500, this sum including the construction of the subway from Dee Village Road to Portland Street, apart from the sewer—a distance of 100 lineal yards—and from Portland Street to Union Street, on the top of the new sewer, the design of which had to be considerably modified and strengthened to receive the subway.

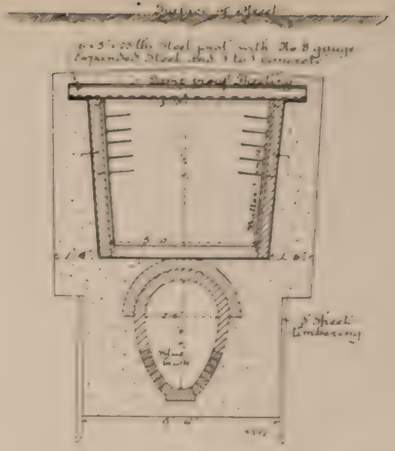


FIG. 6

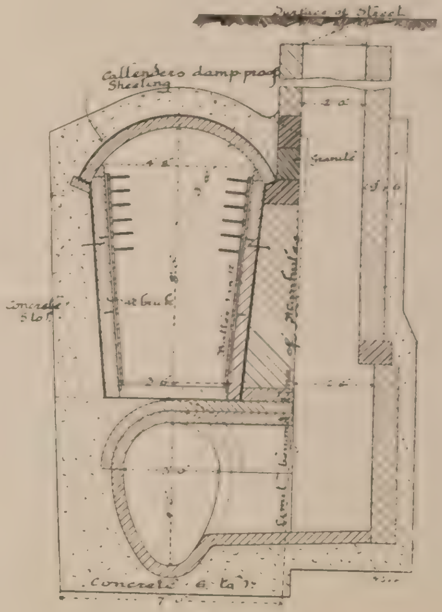
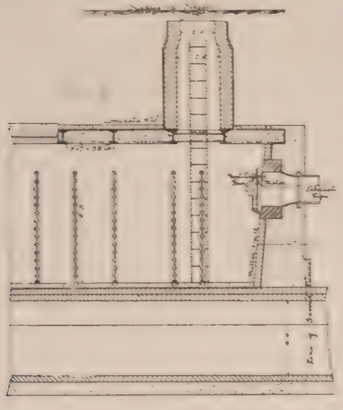
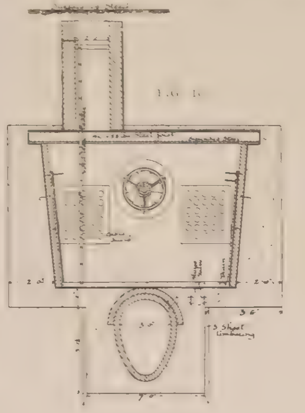


FIG. 7

The subway is designed to carry all feeder cables with their pilot leads for supplying energy to the tramways, and for the distributing mains in the north, west, and central districts of the city. Provision is made for sixty feeder cables capable of supplying energy equal to from 10,000 to 15,000 h.p.





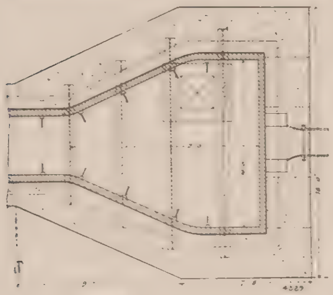
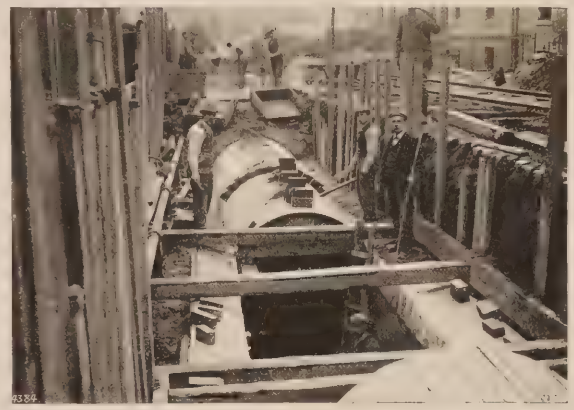


FIG. [illegible]

The space above the sewer, under the [illegible] [illegible] led up the street for a distance of 90 yds., and at the lower end it was only found possible to make the subway 5 ft. high, with a flat roof (see Fig. 6); the width was therefore increased to 5 ft. at the floor level, so that three rows of cables could be placed upon each rack-pin instead of two, as in the lower section; the height is gradually increased and the width decreased, until the depth below the street is sufficient to permit of the ordinary arched type being again adopted. The flat roof is formed with 6-in. by 5-in. rolled steel joists weighing 25 lbs. per lineal foot, spaced 3½ ft. apart, and filled in with 4 to 1 Portland cement concrete, reinforced with a tension bend of No. 8. gauge expanded steel. The bituminous sheeting was carried over the top of these steel beams, and afterwards additional concrete placed on top, sloped as shown (Fig. 6) for drainage, the total thickness of the two layers being 12 ins. Where the [illegible] [illegible] bear upon the walls, a double thickness of sheeting was used.

In the special flat type of subway shown in Fig. 6, the concrete roof was tested for strength. Concrete slabs, 6 ins. thick, gauged 2½ parts of granite metal screened through a 1-in. mesh, and 1½ parts of sand to 1 part of Portland cement, re-inforced with the expanded metal [illegible] referred to, were found to bear, after six months, a load of 1 ton per sq. ft. over a span of 3½ ft. without failure; but the writer is unable to say what the real breaking load would be. The breaking load of the 4 to 1 concrete slabs over a span of 3½ ft., *without* the expanded metal, was 8 cwts. per sq. ft. Judging, therefore, from other experiments, it is probable that the breaking load of the re-inforced concrete over short spans, is four or five times that of the concrete *without* the expanded metal. These loads do not, however, represent the actual strength [illegible] as the bituminous sheeting was covered with

VIEW SHOWING LAGGINGS AND CONCRETE SIDE WALLS OF SUBWAY.



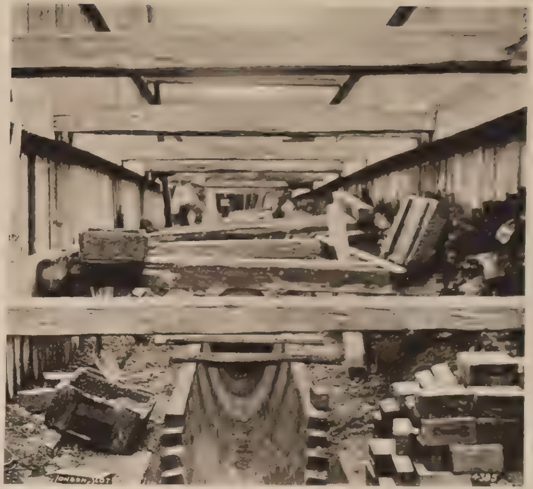
VIEW SHOWING CONSTRUCTION OF SUBWAY--DEE VILLAGE TO PORTLAND STREET.

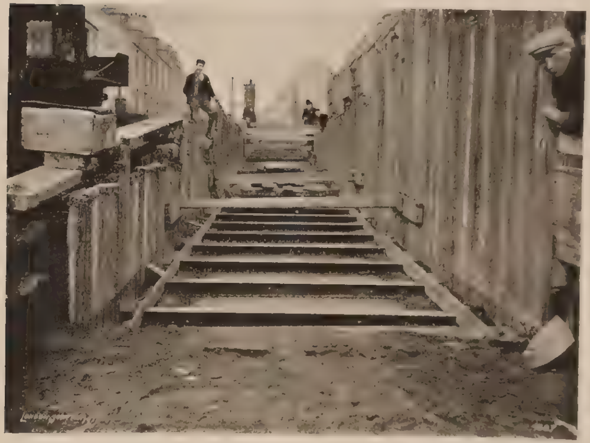
an additional layer of concrete varying from 5 to 6 ins. in thickness.

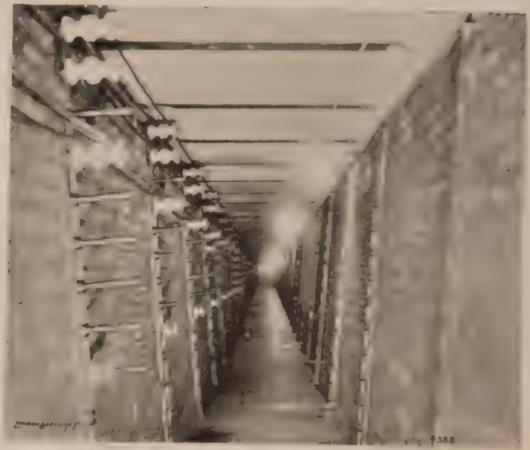
The subway and outfall sewer was practically completed by the end of December, 1901. The work has been very satisfactorily carried out by the contractor for the two sections of the outfall sewer — Mr. Peter Tawse, of Aberdeen. The internal arrangements of lighting, etc., were executed by the electrical department who have also carried out a continuation of the subway, 108 yds. in length, within their own ground, to the new electricity works at Dee Village.

The writer was responsible for the preparation of the contract drawings, and as resident engineer of the Girdleness Outfall Scheme, supervised the construction of the works described.

— R. G. CONWAY


OUTFALL SEWER UNDER SUBWAY—SHOWING OLD SEWER TO THE RIGHT

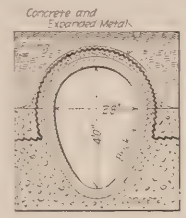

SPECIAL CONSTRUCTION FOR SUBWAY ROOF: VIEW SHOWING EXPANDED STEEL IN POSITION BETWEEN STEEL JOISTS, BEFORE CONCRETE WAS FILLED IN


INTERIOR OF SUBWAY WITH FLAT ROOF

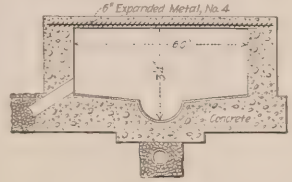
Sewers.

THE use of our material in sewer construction has been in the progress of development for several years. We illustrate in this connection a few sections shewing the best method of use under varying conditions.

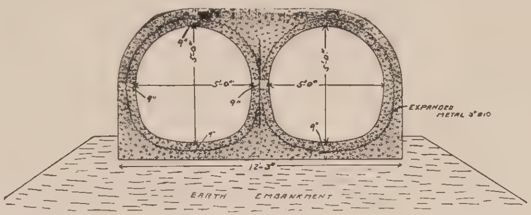
Some four or five years ago a difficulty was met with in the building of a large sewer in Neponset Valley, in Boston, at a location where it was not possible to secure sufficient room for earth-filling on top of sewer without going above grade line. This lack of filling resulted in a continued bursting of the sewer by water pressure. The section in question ran through private property, and the owner would not permit the extra fill to weigh down the original sewer construction. The Chief Engineer of the Metropolitan Sewerage Commission, Mr. William H. Brown, after careful examination of the subject of Expanded Steel and concrete, was induced to make a trial by reinforcing a conduit cover for this sewer. After it had been in use for several years he wrote a letter to the Eastern Expanded Metal Company, stating that the work had been done with comparatively slight expense, and the arch of the sewer had proved abundantly strong and safe to resist the pressure which had resulted in the destruction of previous arches. In other parts of Boston similar difficulties were met with and overcome by the adoption of the same methods and with the same satisfactory results.

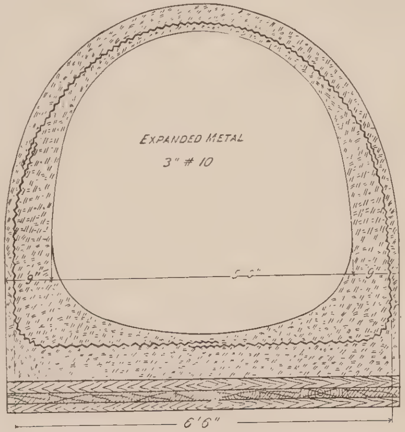


The engineer in charge of public work in Hackensack, N.J., solved the difficulty of securing a permanent roofing for a wide shallow sewer in that city, by the adoption of Expanded Steel and concrete, as shown in accompanying sketch. The location of the sewer made it necessary, in order to carry the volume of water required, to make it very wide and shallow. The sewer had but one foot fall in its length of 800 feet. The accompanying sketch shows the details.



In the erection of a new storage reservoir by the Department of Water of the City of Newark, to be known as the Cedar Grove Reservoir, a certain amount of conduit was required, in some places the section being single and in other places double. We show herewith a view of the double section, which is to be erected upon an earth embankment.





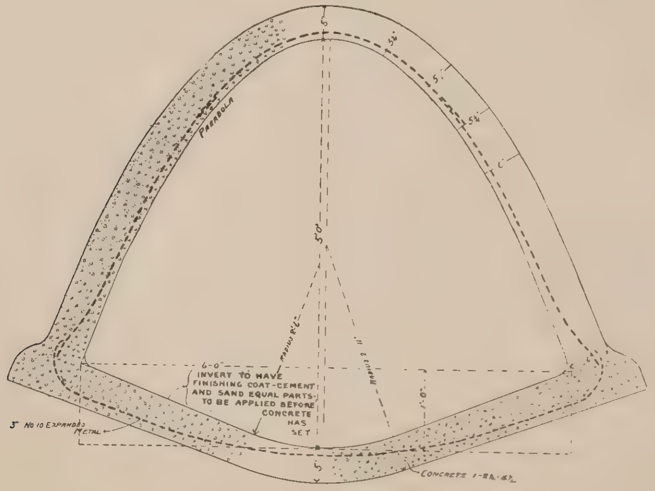
In 1901 there was constructed near the city of Syracuse, N.Y., a remarkable sewer, which carries 20,000,000 gallons of water per day. The sewer is 2,000 feet in length, and there was used in its construction over 50,000 square feet of 3-inch mesh No. 10 Expanded Steel.

Sewers.

THE Harrisburg Intercepting Sewer, three miles in length, was built for the purpose of preventing the discharge of sewage into Paxton Creek during dry weather. This creek is a small stream which rises in the foot hills of the Blue Mountains and flows through a flat valley, averaging about 1,000 feet wide and four miles long, lying parallel with the Susquehanna River, and dividing the City of Harrisburg into two parts, the older business and residential portions of the city and the newer residential portion, situated on the bluffs and hills east of the Paxton Creek Valley.

At the present time there is discharged into this creek, through fourteen of the city sewers, the sewage of upwards of 20,000 people, and as the stream goes nearly dry during summer, its bed is occasionally converted into an elongated open cesspool.

The new intercepting sewer is built along the west bank of the creek, and all the city sewers at present discharging into the creek have been connected with the interceptor in a manner that will allow the ordinary flow of sewage to pass into the interceptor, while the surface water during storms will go directly into the creek, as at present. When the creek is in good flood the sewage can be discharged into it with safety. The flood waters discharged by the sewers will subside more quickly than those from the creek, and hence, during heavy rains, the water in the creek will still be high after the main discharge through the overflows has ceased, and thus the creek bed will be washed clean after each discharge of sewage into it through the overflows.

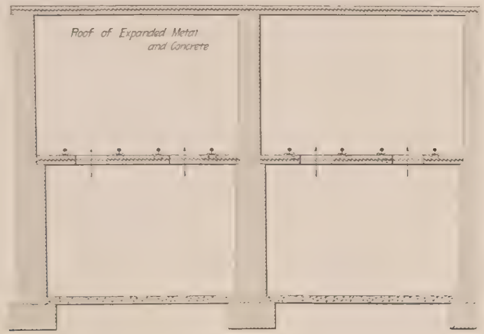


The natural slope of the valley of Paxton Creek is so flat that it would not afford grades steep enough for an intercepting sewer built to receive only the dry weather flow of sewage, and hence it was necessary to make the sewer larger and to maintain a sufficient depth of flow in it by admitting water at the upper end from the creek. This is done by means of a float operating a valve over an orifice admitting the creek water. During dry weather this float will, therefore, maintain a constant depth of water in the upper end of the sewer, while during rain storms, when the adjoining sewers are discharging surface water as well as sewage, the float will rise and shut off the supply of creek water.

The bottom of the excavation in which the sewer is built is of gravel containing a considerable amount of ground water; above the gravel the soil is principally clay. The shape of the invert of the intercepting sewer has been designed to permit its easy construction in this material. It is formed of two inclined planes on a slope of about one to three, joined by an arc of a circle struck from a centre half the height of the sewer. The arch of the sewer is parabolic. The Expanded Steel in the bottom and in the arch is so placed as to allow of simple methods of construction and yet give the best practical results. The sheets of Expanded Steel have a lap of at least two inches at every seam. The concrete is machine mixed in the proportions of 1 part of Portland cement, 2½ parts of sand, and 4½ of ballast, broken to pass through a 1½-inch ring. The invert is finished with a coat of Portland cement mortar ½-inch thick, mixed half cement and half sand, and applied before the concrete has set.

Brick Dry Kilns.

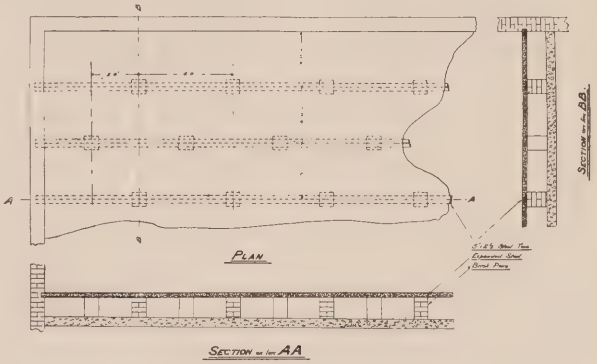
A VALUABLE consideration in the erection of a brick drying house is the floor and roof of the hot-air chamber. In recent years it has been a problem of difficult solution to accomplish the desired results. By the combination of Expanded Steel and concrete the difficulties have been largely overcome. These drying houses are long narrow rooms, through which cars of green brick are sent on iron cars, in order that they may be thoroughly dried before the next step is taken in the process of their manufacture. The accompanying illustration shows how simply this has been accomplished by the use of materials admirably adapted for the purpose. The floors on which the cars travel are built of a slab of concrete, with holes through which the hot air is forced from the lower chamber. In the works from which our illustration is taken, nine of these tunnels were built of a length of 100 feet each, having a capacity of 134 cars of green brick. The hot air from the boiler furnaces is drawn by powerful fans through a hot-air duct underneath the ground, built on a similar principle to the tunnel itself. Having entered the drying chamber, the hot air rises through the openings directly against the cars of green brick, which are travelling by gravity from the upper to the lower end of the tunnels. The same construction has been used in several similar plants.



CROSS SECTION.

Drying Shed Floors.

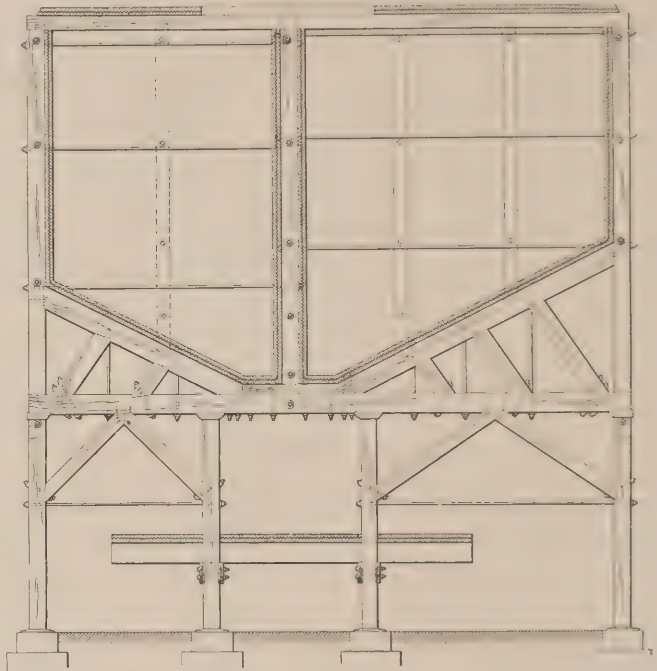
ANOTHER system has been adopted at various places with equal success as follows: Brick piers, 9 inches by 9 inches, are built at say 5 feet intervals and 3 feet apart, pitched on plan. On these piers are placed tee bars at 3 feet centres, and upon these tees are laid Expanded Steel and Concrete Slabs, which are cast for the purpose. A large area can be completed and made ready for use in a very few days, and the whole can be removed for cleaning or other purposes and replaced or renewed according to requirements.



The slabs are composed of fine slag, and Portland cement, 3 to 1, 3 inches in thickness, with a tension bond of No. 8, 3 inch mesh, $\frac{1}{4}$ inch by $\frac{1}{8}$ inch strand Expanded Steel, and are faced with granite chippings and Portland cement; 2 to 1, $\frac{1}{2}$in. in thickness. The S.W.L. of this flooring is 5 cwts. per foot super.

Cement Bins.

IN the re-construction, a year ago, of the Glen Falls Portland Cement Company's plant, at Glen Falls, N.Y., which had been burned by fire, the entire plant was built on concrete fire-proofed lines. The result is a new plant with a capacity exceeding one thousand barrels a day. The floors of the series of buildings constituting the plant exceed 100,000 square feet of area, and are built on the Expanded Metal system. The material was used for various other purposes in the buildings in addition to floors. Among other things there were built a dozen or more mixing and storage bins. We show in the accompanying illustration a cross section of one of the bins. The details are simple. The general framework was built of heavy wooden timber firmly bolted together, and the bottom, sides and top were covered with reinforced concrete, the interior surface being neatly troweled with cement.



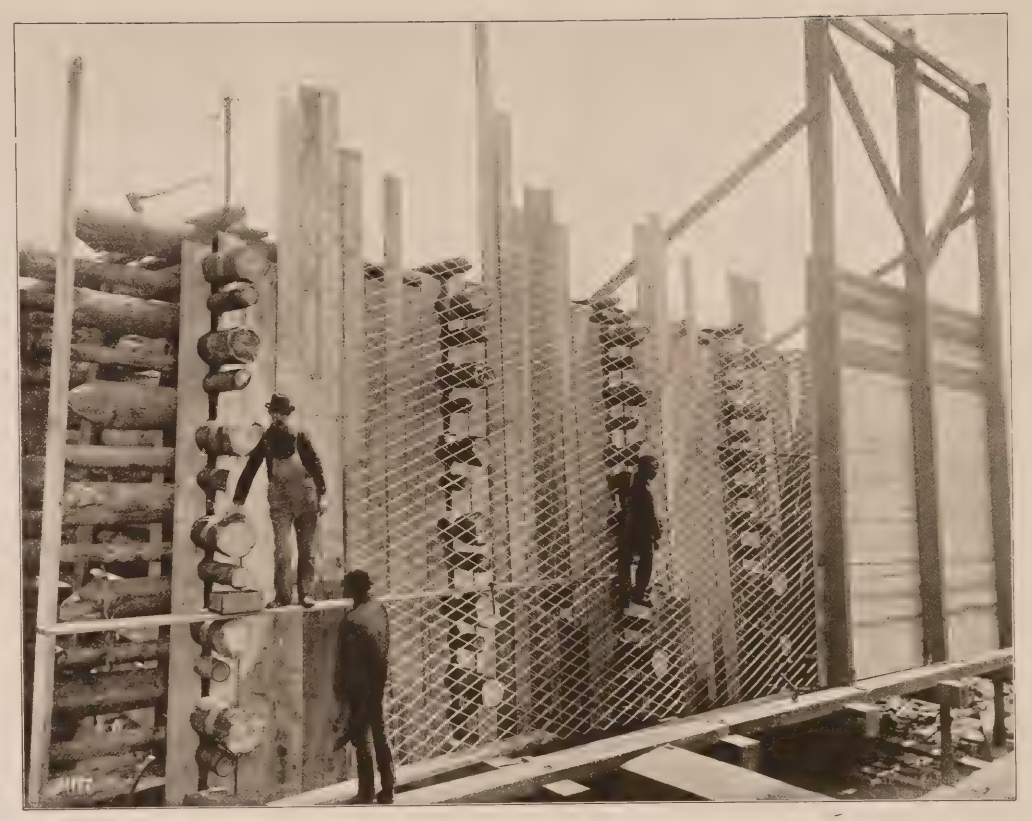
A recent development is the application of Expanded Steel lath with a system of light iron framing, upon which, as a supporting fabric, are built the walls for hot-air conduits in large power plants. The prevailing method of building these conduits has been by the use of heavy sheet iron. It was found, however, that the heavy iron conduits lost much of their efficiency by the radiation of the heat. The steel and concrete scheme proves to be quite as economic in construction as the other, and has many other advantages.

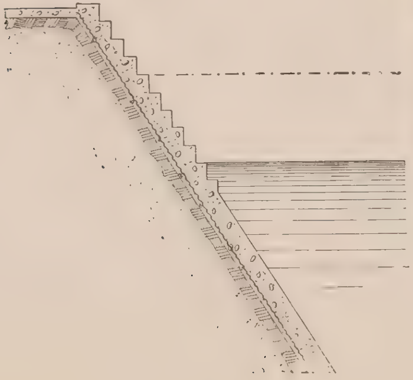
One of the most up-to-date works in this country is The Saxon Portland Cement Co.'s works at Fulbourne, near Cambridge. The reinforced concrete throughout is on the Expanded Metal system.

Where variable loads have to be dealt with, as in bins, hoppers, silos, flooring, etc., Expanded Metal construction offers many advantages over any other system, as on account of the uniform elasticity of the structure the walls, floors, etc., easily recover on the removal or variation of the load. It has in fact been proved from practical test that an overloaded slab which had deflected $\frac{5}{8}$-inch recovered its normal condition after its load had been removed, a practical impossibility in un-reinforced concrete where the high tensional quality is wanting.

A Pacific Coast Dry Dock.

A CERTAIN advantage to the dry dock facilities of the Pacific Coast has been accomplished by the San Francisco Dry Dock Company, at its yards, Hunter's Point, Cal. The plans for this dock were prepared by the Chief Engineer State Harbour Commissioners, San Francisco. In the construction of this dock the entire chamber has been concrete lined, reinforced with Expanded Steel, except for the sides of the approach, seat for the caisson and the apron arch, which are of cut granite masonry.

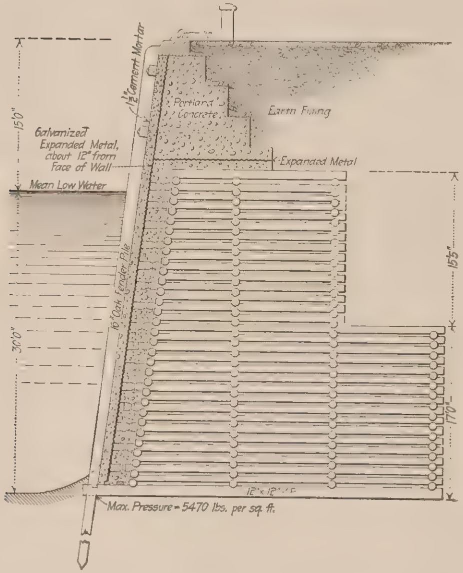


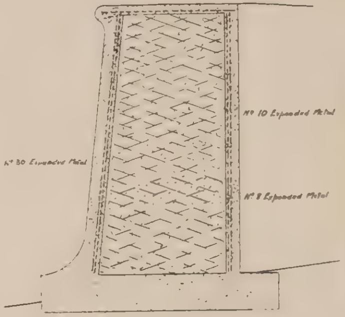


The accompanying illustration shews a small section of the side of the dock, and indicates the manner in which the Expanded Steel was used to bond the concrete sides. It might be mentioned that between the concrete lining and the rock surface, a thorough coating of damp-proofing was used.

Concrete Retaining Walls.

THE accompanying illustration scarcely needs any description. It is that of a concrete retaining wall wherein a stone filled crib is faced with a heavy mass of concrete, whose surface is bonded together by the use of Expanded Steel. The major portion of the work was erected two years or more ago, and it proved so satisfactory that there is now in progress still more of the same class of construction. In the building of this dock wooden cribs were built on land and floated out and sunk at the spot where they were to form the dock. A double line of wooden sheathing surrounded the crib-work, and there was placed in the middle of the space thus formed a series of sheets of 6-inch mesh Expanded Steel, galvanised. This was then built into place in the sand, and 2 inches of concrete surrounded the entire crib-work. In all, about 50,000 square feet of Expanded Steel were used in this work.





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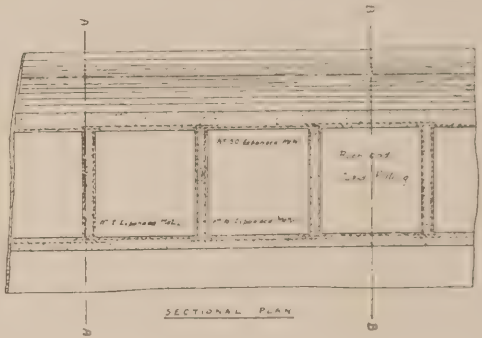


SECTIONAL PLAN

The two illustrations above shew a sectional plan and cross section of a method for constructing a re-inforced concrete retaining wall for shore defence, etc., etc. The sketches fully explain themselves. The compartments are formed by means of temporary centering, and when this has been struck they are filled in with rock and sand or other suitable filling, after which the top is laid and finished.

The Expanded Metal Company's Systems.

HOW TO SPECIFY.

Flooring.

__________yards super in Expanded Steel and Concrete Flooring, as follows :—

Supply and erect temporary wood centering, and on same lay No.___ 3 in. mesh_ strands bare, Expanded Steel, to be obtained of the New Expanded Metal Company, Limited, with one mesh overlap where the sheets join, the long way of the mesh running from support to support, and on same lay concrete composed of four parts of approved aggregate broken to pass a $\frac{3}{4}$ in. mesh sieve, and having about 30 per cent. of fine stuff in its measure, to one part of best Portland cement, turned three times dry and three times after water has been added, carefully scraped into the meshes and well trodden and spaded down, and laid so as to thoroughly embed the Expanded Steel, ___ins. in thickness, finished to a fair screeded surface to receive facing (measured separately), or, preferably, finished with a topping of clean sharp sand or granite chipping, and Portland Cement in equal proportions, finished from the hand float (or as may be desired), while the concrete is "green."

Or, if the Company's Patent Flooring is to be used,

Flooring.

yards super Cambered channel and Concrete Ribbed, Expanded Steel and Concrete Flooring, as follows :—

Supply and erect cambered steel channels and other steelwork to be obtained of the New Expanded Metal Company, Limited, temporary wood centering, fill in channels with concrete as above, forming 6 in. ribs, and on same lay No.____ 3 in. mesh __________ strand bare, Expanded Steel, to be obtained of the above Company, etc., as last.

Partitions.

________ yards super in Expanded Steel Lathing and Plaster Partitions, as follows :—

Supply and erect metal grounds to be obtained of the New Expanded Metal Company, Limited, according to their instructions, and cover same with plaster composed of ordinary lime and hair mortar gauged three to one with best Portland cement, and finished smooth on both sides (or as may be desired) with Keene's or Parian cement for interior work, with Portland cement for exterior work, or, cover same with Ward's Granite Silicon, Asbestic, or other suitable plaster finished smooth on both sides (or as may be desired).

Suspended Ceilings.

__________yards super, in Expanded Steel Lathing and Plaster Suspended Ceilings, as follows :—

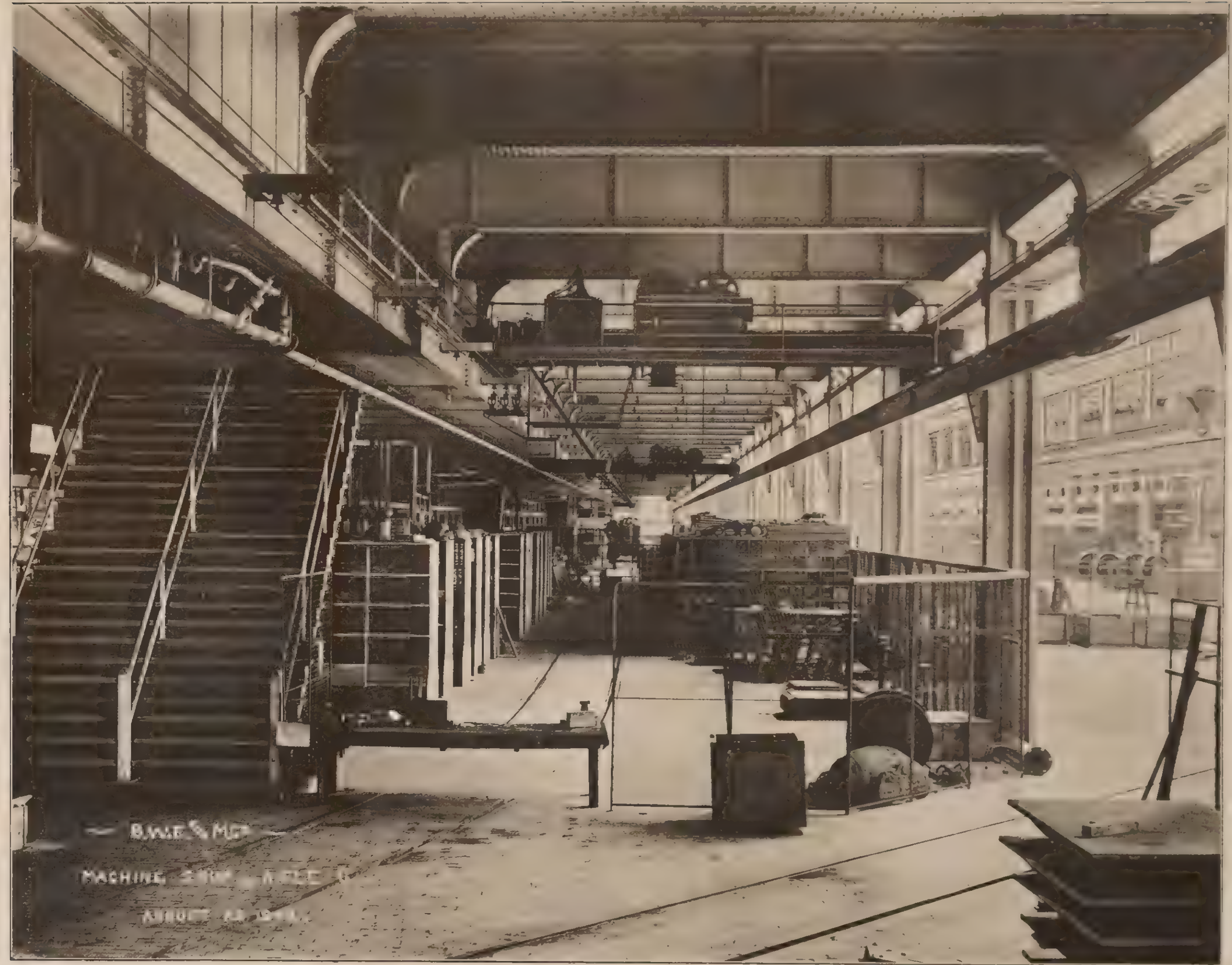
Supply and erect metal grounds to be obtained of the New Expanded Metal Company, Limited, according to their instructions, and cover same with Plaster, etc., as may be desired.

Steelwork Encasing.

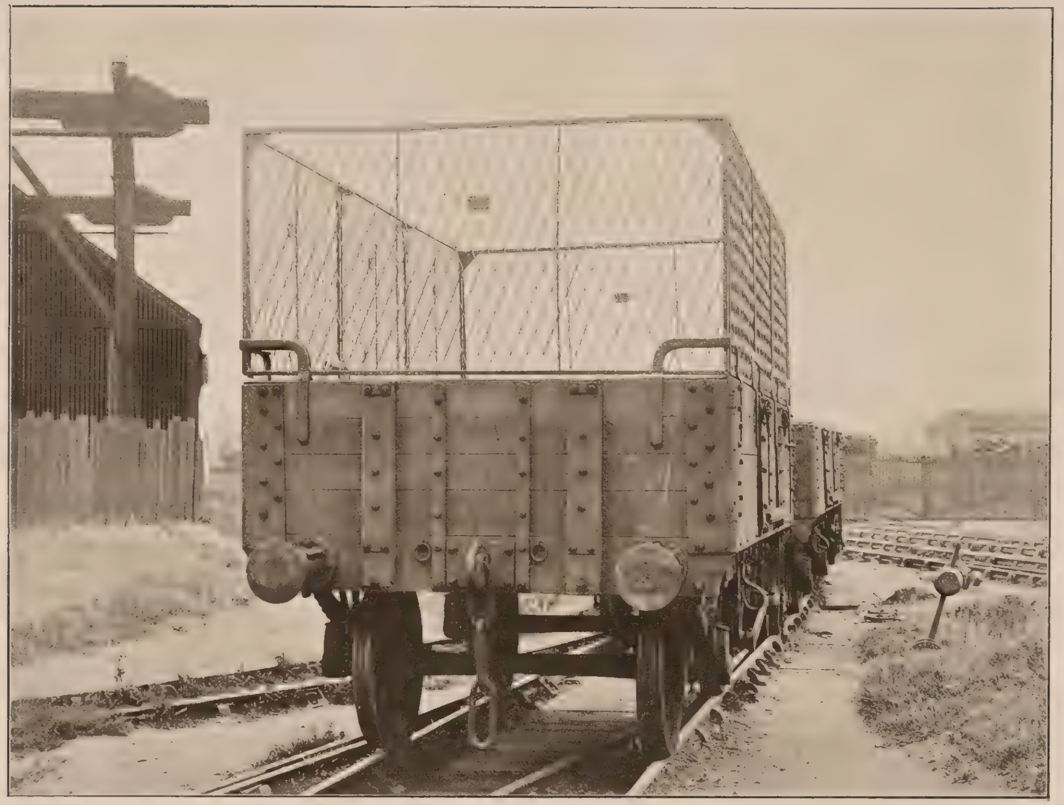
____yards super, in Expanded Steel Lathing and Plaster Encasing to steelwork as follows :—

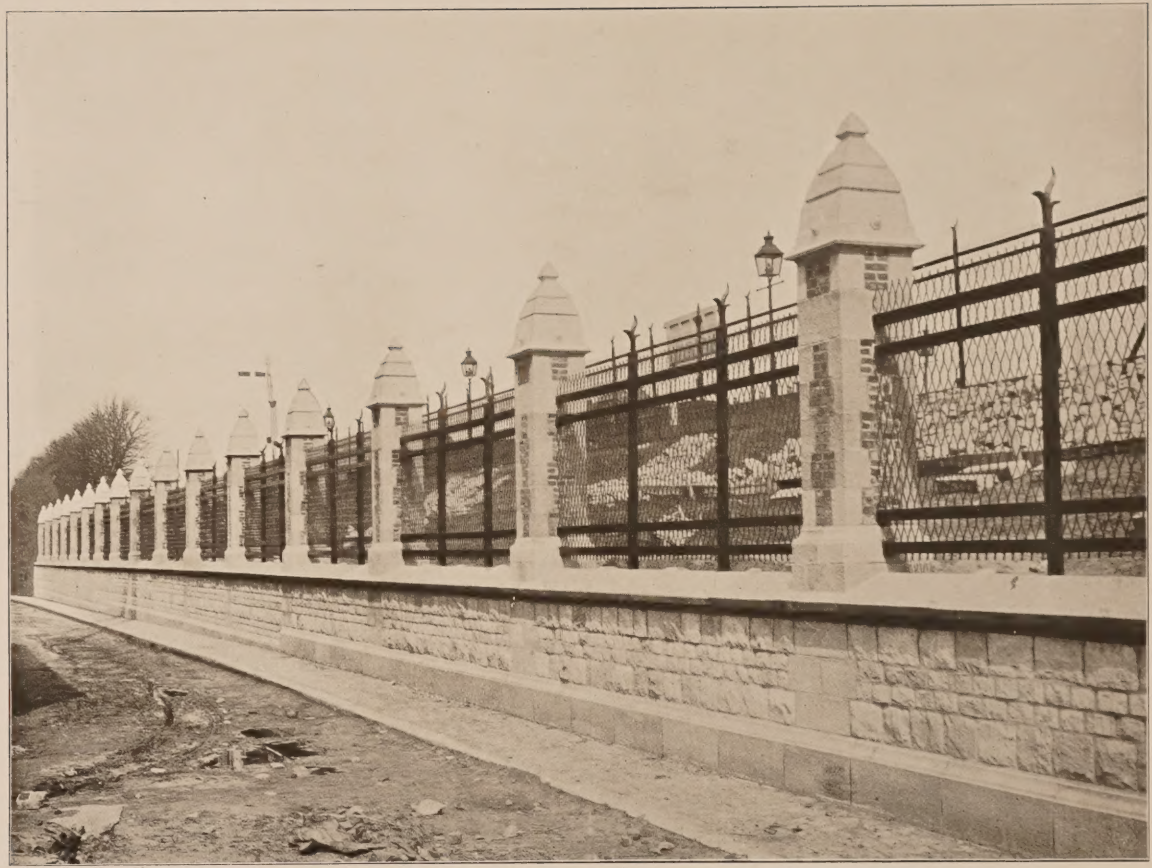
Supply and erect metal grounds to be obtained of the New Expanded Metal Company, Limited, according to their instructions, and cover same with plaster, etc., as may be desired.

Note.—The Company is prepared to submit designs and tenders for any work on their systems, and to carry out such work for the general contractor or otherwise as may be desired; and a lump sum price should be included in the bill of quantities for such work, the contractor adding his profit or otherwise as directed.



Removable Openwork Partitions and Guards.
The British Westinghouse Electric and Manufacturing Co., Ltd.,
Trafford Park, Manchester.





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